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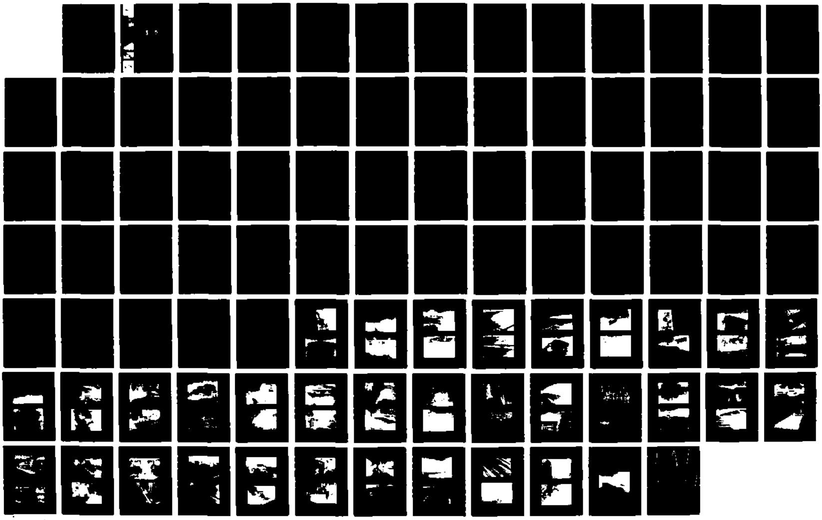

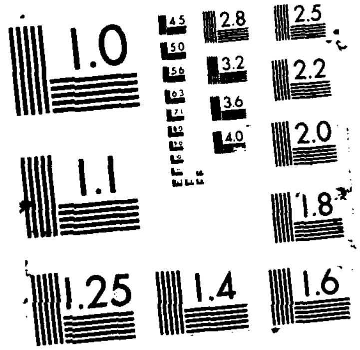
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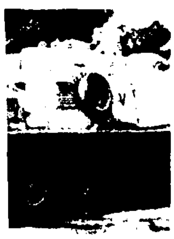

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TECHNICAL REPORT GL-87-18

COST-EFFECTIVE SURFACING FOR TRACKED-VEHICLE TRAFFIC

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by

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US ARMY ENGINEER WATERWAYS EXPERIMENT STATION

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Final Report

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There is a need for cost-effective surfacings for areas subjected to tracked-vehicle traffic to reduce maintenance costs and improve safety. Surveys of several locations with tracked-vehicle traffic were made to observe pavement conditions and maintenance requirements. These observations demonstrated that pavement performance depended on how local personnel perceived their problems and local repair methods.

A test section to evaluate several mixtures was constructed and tested at Fort Stewart, Georgia. The items tested were these:

a. Fiber-reinforced concrete.
b. Wire-mesh-reinforced concrete.
c. Roller-compacted concrete pavement (RCCP) in depths from 4 to 10 in.
d. Concrete paving blocks over sand-grid base.

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Fibrous concrete
Latex-modified asphalt
Paving blocks
Roller-compacted concrete pavement
Sand grids
Steel-slag asphalt
Tracked vehicle

19. ABSTRACT (Continued).

e. Latex-modified asphaltic concrete.
f. Steel-slag asphaltic concrete.
g. State of Georgia standard E-Mix asphaltic concrete.

The properties of the various items before and after construction were determined and evaluated. Trafficking on the test section consisted of normal traffic with M60A-1 tank and M-88 tank retriever traffic in addition to minor car and light truck traffic. Locked-track turns were performed on each item, and the pavement surface was evaluated.

Results of this study indicated that all items tested provided a satisfactory surface when properly prepared. RCCP provides a suitable surface for roads and parking areas at favorable costs compared to conventional concrete. Paving blocks provide a suitable surface and the ability to remove and replace or relevel individual blocks can offset their high-cost, labor-intensive installation. The asphalt pavements evaluated, while not as resistant to abrasion as concrete pavements, are less expensive to construct and repair.

PREFACE

This study was conducted by the Geotechnical Laboratory (GL), US Army Engineer Waterways Experiment Station (WES), Vicksburg, Mississippi, for the Office, Chief of Engineers (OCE), US Army, under the Operational Maintenance, Army Project. Mr. A. F. Muller, OCE, was the Technical Monitor. The work was performed from March 1983 until December 1985. This report was prepared under the project entitled "Cost-Effective Surfacing for Tracked-Vehicle Traffic."

WES personnel actively engaged in the conduct of this project included Mr. Harry H. Ulery, Dr. Thomas D. White, Mr. Jim W. Hall, Jr., and Dr. Elton R. Brown, Pavement Systems Division (PSD), GL. The work was conducted under the general supervision of Dr. White, former Chief, PSD, GL; Mr. Harry H. Ulery, Chief, PSD, GL; and Dr. William F. Marcuson III, Chief, GL. PSD personnel engaged in testing and analysis included Messrs. Timothy W. Vollor, David Pittman, Timothy J. McCaffrey, Herbert McKnight, David P. Reed, Joey K. Simmons, and James E. Shoenberger. This report was written by Mr. Shoenberger.

The Fort Stewart test section plans and specifications were prepared under the general supervision of COL Robert W. Glenn and Messrs. Thomas Houston and William Wilkinson, Directorate of Engineering & Housing. Mr. Houston acted as the contracting officer.

COL Allen F. Grum, USA, was the previous Director of WES. COL Dwayne G. Lee, CE, is the present Commander and Director. Dr. Robert W. Whalin is Technical Director.

CONTENTS

CONVERSION FACTORS, NON-SI TO SI (METRIC) UNITS OF MEASUREMENT

Non-SI units of measurement used in this report can be converted to SI (metric) units as follows:

Multiply	By	To Obtain
degrees (angle)	0.01745329	radians
Fahrenheit degrees	5/9	Celsius degrees or Kelvins*
feet	0.3048	metres
gallons per square yard	4.5273	cubic decimetres per square metre
gallons (US liquid)	3.785412	cubic decimetres
inches	2.54	centimetres
Poise (absolute viscosity)	0.10	pascal second (Pa·s)
pounds (force) per square inch	6.894757	kilopascals
pounds (mass)	0.4535924	kilograms
pounds (mass) per cubic inch	27.6799	grams per cubic centimetre
pounds (mass) per cubic yard	0.5932764	kilograms per cubic metre
square feet	0.09290304	square metres
square yards	0.8361274	square metres
tons (2,000 pounds, mass)	907.1847	kilograms

* To obtain Celsius (C) temperature readings from Fahrenheit (F) readings, use the following formula: $C = (5/9)(F - 32)$. To obtain Kelvin (K) readings, use: $K = (5/9)(F - 32) + 273.15$.

COST-EFFECTIVE SURFACING FOR TRACKED-VEHICLE TRAFFIC

PART I: INTRODUCTION

Background

1. The abrasion caused by tracked vehicles results in damage to asphalt pavements where locked-track turns and/or fuel spills occur. Improved surfacing materials are needed to provide a cost-effective surfacing for pavements subjected to tracked-vehicle traffic.

2. The current practice in the Army is to construct rigid pavements in areas subjected to locked-track turns and/or fuel spills such as intersections, maintenance areas, and parking areas. The design for a rigid pavement subjected to tracked-vehicle traffic is provided in TM 5-822-6. The minimum thickness of rigid pavement specified is 6 in.* A study for reducing this minimum thickness was conducted by the US Army Engineer Waterways Experiment Station (WES) (Jackson 1984). The results of this investigation indicated that thinner sections of reinforced portland cement concrete (PCC) slabs would support the M-48 tank on a high-strength base course. It also showed that thin sections of fibrous concrete may be satisfactory when placed on a high-strength base course. Since the investigation by Jackson considered only high-strength base courses, the use of fibrous concrete is limited to high-quality materials. The follow-up study reported herein was initiated to evaluate thin PCC sections placed on an average-strength base course and also to look at other surfacing materials that may be more cost-effective.

Objectives

3. These were the objectives of this study:

   a. To evaluate thin reinforced PCC slabs on an average-strength base course having a subgrade modulus k of 200 pci.

   b. To evaluate promising materials and pavement systems that would improve the cost-effectiveness of pavements subjected to tracked-vehicle traffic.

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* A table of factors for converting non-SI units of measurement to SI (metric) units is presented on page 3.

Scope

4. To satisfy the objectives, the following items were accomplished:

   a. Several military installations with tracked-vehicle traffic were visited to ascertain pavement problems being experienced.

   b. Materials and pavement systems were evaluated as to their promise of being cost-effective as a surfacing for tracked vehicles.

   c. Test sections were built on an average-strength base course with a k of 200 pci for rigid pavements and a California Bearing Ratio (CBR) of 50 for flexible pavements.

   d. Tracked-vehicle traffic was applied to the test sections and the performance of the surface was monitored.

   e. A cost analysis of the test sections was performed.

PART II: FIELD INVESTIGATIONS

Background

5. Four locations were visited to evaluate track damage to asphalt concrete pavements: Fort Bliss, Texas; Fort Hood, Texas; Fort Stewart, Georgia; and Detroit Arsenal, Michigan. These locations had asphalt pavements that were exposed to tracked-vehicle traffic. Core samples were taken for analysis at all locations except Detroit Arsenal, where data were already available. WES provided the mix design and technical assistance during the construction of this pavement; therefore, the data were available.

6. Intersections and along pavement edges were the problem areas for tracked vehicles on pavements. Wherever a tracked vehicle had turned, problems with scuffing or shoving occurred. Tracked vehicles, because of their width and speed, normally travel with their inside track on the middle of the traffic lane and the outside track on the shoulder or gutter causing distress to these structures (Photo 1). This traffic caused the outer edge of the pavement to wear faster than other areas, resulting over a period of time in the edge rounding (Photo 2).

7. Tank-crossing areas also caused problems. When the crossing was from a dirt road, in addition to the wear on the pavement, there were problems with dirt being dumped from the tank tracks onto the pavement. A dust hazard also occurred at dirt road crossings (Photo 3). With enough cross traffic with tracked vehicles, differential wear will result to these pavement areas.

8. Fuel spills are a major concern in tracked-vehicle maintenance areas (Photo 4). Fuel, oil, and other vehicle fluid leaks were common with these tracked vehicles. This, along with accidental spills incurred while performing maintenance, caused pavement distress.

Fort Bliss

9. A total of 18 core samples were taken at Fort Bliss. Table 1 lists the approximate locations and the thickness, specific gravity, and density of each layer of the cores. The cores were taken from three separate roads--six samples were taken from each. The top layer of asphalt mixture was removed and evaluated. This evaluation included determination of density, measurement

of properties of the aggregate and asphalt, and recompaction of the asphalt mix for comparison with the original field core densities (Table 2). The average density of the field cores was greater than the 98 percent of laboratory density required by specification. The gradation of the aggregate extracted from the cores showed the percentage passing the No. 200 sieve to be too high. The average percent voids in the total mix averaged below 3.0 percent. The Marshall stabilities were above 3,000 lb. The field cores from locations A and B had higher densities and higher penetrations of the recovered asphalt than did those from location C (Tables 1 and 2).

10. The asphalt pavement distresses found at Fort Bliss were similar to those found throughout this study. The major damage to asphalt pavements occurred at intersections or in areas where turns were made (Photo 5). At Fort Bliss, this problem was being solved by replacing the damaged asphalt pavement with reinforced PCC (Photo 6). The straight sections of asphalt pavements were generally in good shape except for some slight corrugation (Photo 7). On roads with a curb-and-gutter system, the tanks rode in the gutter or on the curb and caused severe damage to both (Photo 8).

Fort Hood

11. At Fort Hood, a total of 15 core samples were taken--three each at five different locations. Table 3 lists the approximate locations and the thickness, specific gravity, and density of each layer of the cores. The top layer of each of these cores was removed and its properties were evaluated. This evaluation included determination of density, measurement of properties of the aggregate and asphalt, and recompaction of the asphalt mix for comparison with the original field core densities (Table 4). The average density of the field cores was greater than 98 percent of laboratory density required by specification. Because of the limited material available from the field cores, all cores were combined for evaluation and recompaction purposes. The gradation of the cores showed the percentage of aggregate passing the No. 200 sieve to be too high. The percent voids in the total mix was low, and the stability of the recompacted mix was approximately 5,000 lb. The penetration of the recovered asphalt cement was 22.

12. Fort Hood had many PCC and asphalt concrete pavements that appeared to be in good condition except for the edges rounding off (Photo 2). This was

caused by the tracked vehicles running on the shoulder and the edge of the pavement. The PCC pavements are more difficult to repair and Fort Hood is currently seeking to replace the pavements with asphalt pavements to simplify repairs when they become necessary. Fort Hood also had many PCC pavement sections at tank crossings on asphalt roads. A problem had been encountered over the years as the asphalt pavement was overlaid, resulting in the formation of a dip at the PCC crossing (Photo 9). These dips had become severe. To alleviate this situation, concrete ramps were built up to these crossings and asphalt pavement was placed continuously throughout the road. These concrete ramps solved the major problem in crossing asphalt pavements--edge cracking. Fort Hood was increasing the use of asphalt concrete, which should have increased the amount of maintenance required while simplifying the repairs. Fort Hood had several parking and loading areas overlaid with asphalt pavement. These areas had received repeated fuel spills and had experienced damage from traffic (Photo 10).

Fort Stewart

13. At Fort Stewart, 16 core samples were taken--four each at four different locations. Table 5 lists the approximate location and thickness, specific gravity, and density of each layer of the cores. The top layer of asphalt of each core was removed and its properties were evaluated. This evaluation included testing the properties of the aggregate and asphalt used in the mix (Table 6). The top layer of the field cores was too thin to provide enough material for density testing or for preparing recompacted samples. The gradation of the surface course was very fine with more than 82 percent of the aggregate passing the No. 4 sieve. The percentage of aggregate passing the No. 200 sieve was 9.0 percent. The asphalt was very hard with a penetration of 13.

14. The survey of the pavements at Fort Stewart revealed distress similar to that observed at the other locations visited. Damage had occurred most frequently at intersections or wherever turns were made. Also, damage had occurred at the road edge, shoulders or gutters, or where there was heavy tank traffic (Photo 11).

Detroit Arsenal

15. A visual survey was made of these roads which were constructed in accordance with the US Army Corps of Engineers specifications (1984). The roads in the other three surveys were constructed in conformance with State specifications, which had similar requirements. These roads had received a minimal amount of tracked-vehicle traffic; the average daily traffic was only one to two tracked vehicles. The aggregates in these pavements consisted of approximately 50 percent slag (Photo 12). Table 7 gives the density and mix analysis of the asphalt mixture at the time placed. The ratio of the average field density to the average laboratory density shows the density to be approximately 3 percent below specified limits. Other mixture properties are within the specification limits.

16. The pavement was in good condition with only a few surface defects (Photo 13). There was some surface scuffing where tracked vehicles had turned (Photo 14). This asphalt pavement was placed over PCC pavement and the underlying contraction joints had reflected through (Photo 15). These cracks were small and had not raveled. During construction, a problem was encountered with the slag aggregate in that the specific gravity of the slag varied so much that it was difficult to maintain the proper void content in the mix.

PART III: TEST SECTION

Background

17. A test section was constructed at Fort Stewart to study the effects of tracked-vehicle traffic on various pavement types. Several different types of pavement surfaces were reviewed and evaluated, including various PCC mixes, asphalt cement mixtures with and without additives, and other specialty-type construction materials.

18. These various pavement types were incorporated into a single test section to form a tank access road at Fort Stewart, Georgia. The access road leads from the armory motor pool to a nonpaved tank trail behind the motor pool. Figure 1 shows an overall layout and the individual test items as well as the size, type, and date of placement of all items. The subgrade preparation and base and test section construction took place in August and September 1984.

19. The subgrade for the entire test section required no preparation other than the excavation required to obtain desired grade prior to the start of construction. A layer of sand-clay base course was placed beneath each of the 12 pavement items to yield a total constructed section thickness of 12 in. For the entire test section, the base course thickness varied from 2 to 10 in. Field tests, including plate bearing and CBR, were conducted on the in-place subgrade (Tables 8 and 9) at the locations shown in Figure 2. A comparison of these test results and the design curves showed that the subgrade would provide adequate strength for the subsequent base course and test section (Department of the Army 1978).

20. Traffic on the test section includes these tracked vehicles: M-88's (tank retrievers); M-60A1's (battle tanks); and M-223's (armored personnel carriers); and also assorted personnel-vehicles. The majority of the personnel-vehicle traffic is limited to items K, J, I, H, L, and M (Figure 3). The tracked-vehicle traffic is made up of approximately 50 percent M-88 traffic, with M-60A1 and M-113 traffic making up the balance. An accurate recording of traffic frequency, type, or routes used was not available. Estimates of tracked-vehicle traffic were provided by local maintenance personnel (Figure 3).

21. The effects of traffic discussed in this part include not only

distress caused by traffic but also that caused by construction or design deficiencies. The latter causes of distress tend to appear shortly after construction or very early in the life of the pavement.

22. Observations of the effect of an M-88 tank retriever's locked-track turns on the performance of each item were made approximately 1 month after construction (Photo 16). Observations on the performance of each item were also made after long-term traffic. Figure 4 shows a layout of the test items and the visual distresses that were noted from long-term traffic. These observations were made in May 1985, approximately 33 weeks after construction. Items A, B, C, D, E, G, I, J, K, and L are in areas not normally subjected to turning traffic.

23. The following paragraphs provide a description along with the design, construction procedure, and performance of each test item.

Fiber-Reinforced Concrete (FRC), Item A

Description*

24. FRC is conventional concrete that contains randomly dispersed fibers of short length and small cross-sectional area. The types of fibers commonly used include steel, glass, plastics (including nylon, polypropylene, polyethylene, polyester), and other synthetic and natural materials (Williamson 1975). Steel fibers have been used most frequently because of their wider application and overall performance. Fibers are added to the concrete mix to increase its load-carrying capacity and to inhibit cracking (Howell 1982). These improvements in flexural strength result in thinner, more economical sections and an increase in joint spacing. Depending on the mix parameters involved, established concrete construction procedures can be used for FRC application. Existing concrete specifications can be used for the manufacture and placement of FRC with some added requirements for differences in materials and technique.

Design

25. The FRC test item was constructed 20 ft wide by measures 20 by 21 ft long and was placed 2 in. thick. Dramix ZL 30/.50, a steel fiber manufactured by Bekaert Steel Wire Corporation, was used as the reinforcement in

* Current practice requires prior approval (Department of the Army 1987) before constructing with FRC.

the FRC. These fibers are nonbonded and have a length of 1.2 in. and a diameter of 0.02 in. The fibers have formed or "hooked" ends to provide for anchorage. Type I portland cement was used in preparation of this concrete. The aggregate was of the same type and blend as that used for all PCC (Table 10).

Construction

26. The FRC was placed 2 in. thick. The edges of the pavement were formed with 2- by 4-in. lumber. The steel fibers were added to the concrete at the transit truck mixer by manually pouring the fibers onto the aggregate belt feeding the mixer. The concrete was discharged directly from the mixer onto the prepared surface within the test item. A slump of approximately 3 in. was maintained to make the FRC workable enough to screed and float properly. Screeding was accomplished with 12-ft-long by 4-in.-thick lumber. A 3/4-in.-diam pipe was used along the crown for proper grade and slope control. Periodically, small clumps of fibers and cement paste (approximately 2 in. in diameter) formed during the mixing process, but were broken up with rakes during placement (Photo 17). The final surface was floated but remained very rough over approximately 10 percent of the surface area as a result of segregation of the larger aggregate during placement and inadequate hand finishing procedures (Photos 18 and 19). Proper finishing procedures were difficult to achieve with hand floats; mechanical finishing devices could have provided an improved final surface.

Performance

27. The FRC pavement is in excellent condition after an estimated 2,100 tracked-vehicle passes. Neither normal traffic nor locked-track turns by an M-89 tank retriever had caused any distress in the item (Photo 20). Two beam samples were cut from this item (Figure 5). Table 11 gives the results of the flexural strength tests performed on these samples.

Reinforced Concrete, Item B

Description

28. Reinforced concrete contains welded wire fabric or deformed bar mats arranged in a grid system. Reinforced concrete, as with plain concrete, may be constructed with either stationary forms or by slip forming. The reinforcing steel is placed prior to placement of the concrete and is held in

position with the use of chairs to prevent movement during placement of the concrete. The addition of steel reinforcement to concrete has several advantages including (a) a reduction in slab thickness, (b) greater spacing between transverse joints, and (c) a reduction in width of crack opening. Concrete has been used historically wherever tracked-vehicle traffic or fuel spills occur.

Design

29. The reinforced-concrete item was constructed 24 ft wide by 21 ft long and was placed 4 in. thick. Two layers of No. 10 wire mesh, feet held 1 in. apart by chairs, were used as reinforcment. A Type I portland cement was used in preparation of the PCC. The aggregate was of the same type and blend as that used for all PCC (Table 10). The slump of the mix was maintained between 1 and 2 in.

Construction

30. The wire-reinforced concrete was placed in a 4-in.-thick lift. The concrete was mixed in a transit truck mixer and discharged directly onto the test item location. The base was wetted immediately prior to placement to prevent absorption of the water from the concrete mixture. The placement was formed with 2- by 4-in. lumber, and a 3/4-in. pipe was used along the crown for proper grade and slope control (Photo 21). The roller-compacted concrete pavement (RCCP) in Item C was cut back to expose a 4-in.-vertical face for this item. The wire-mesh einforcement was placed in two layers and held in place by chairs. The concrete slump of 1 to 2 in. made placement around the wire mesh difficult. The surface texture remained somewhat open, even after floating (Photo 19).

Performance

31. The reinforced concrete pavement was in good condition after an estimated 2,100 tracked-vehicle passes (Photo 22). A few hairline cracks had appeared, but they did not seem to penetrate the full depth and were random in occurrence. Locked-track turns by an M-88 tank retriever caused no distress to this item.

RCCP, Items C, F, H, I, J, K, and M

Description

32. RCCP is a construction process using a low- or zero-slump concrete

mix placed on a prepared base course with an asphalt spreader or other suitable equipment (American Concrete Institute 1983; Department of the Army 1986 (draft)). To date, the asphalt spreader has provided the best results for grade control and surface texture when compared with other placement methods. The compaction and finishing procedures are accomplished by a vibratory roller making three to four passes, and the use of a rubber-tired roller can improve the surface texture (Burns 1976). This method of construction eliminates the cost of labor, equipment, and materials for forming, finishing, and form removal. This technique can be used to place large volumes of concrete in a short period of time using minimal labor and equipment. The reduction of water in the RCCP mixture reduces the workability time; therefore, additional attention should be given to the sequence of construction. This limited workability time also limits the distance the mixture can be transported from the mixing plant to the construction site. Conventional concrete pavement curing procedures are satisfactory for RCCP. In most cases, the lower water content of the zero-slump concrete mixture will reduce shrinkage in RCCP. This procedure was developed to produce an economical and durable surface where the importance of surface smoothness was minimized. There has been concern with surface smoothness when RCCP construction procedures are used. Experience with RCCP has proved that an acceptable surface can be obtained. This construction procedure can be used to surface tank roads, parking, and washing facilities. RCCP provides an alternative to conventional concrete and other materials for tracked vehicles.

Design

33. Type I portland cement was used in preparation of these mixes. Tables 10 and 12 contain the aggregate gradation and the mix design of the zero-slump concrete. The aggregate was a blend of concrete sand and granite conforming to American Society for Testing and Materials (1984) No. 57 grade aggregate. The water/cement ratio was 0.33 with an assumed 1-percent air content. The same mix was placed in various thicknesses from 4 to 10 in.

Item C

34. Construction. This RCCP item was placed in an area approximately 44 ft wide by 21 ft long, in one 6-in. layer. The zero-slump concrete was discharged directly from the transit mixer onto the base and was spread with a G-660 Gradall bucket (Photos 23 and 24). A paving-spreader machine is recommended for placing RCCP; however, for this small item, this method was

satisfactory. The Gradall was also used to prepare the area prior to placing the concrete. Stringlines were set up around the perimeter for horizontal grade alignment. Wooden beams were staked in place on one edge of the item to form a vertical surface to compact against. The concrete plant (E & B Concrete Co., Fort Stewart, Georgia) was on the installation within half a mile of the construction site. The base was wetted prior to the placing of the RCCP. The mix was transported in standard 9-yd^3-capacity drum transit mixers (Photo 25). Approximately 1 gal/yd^3 of water had to be added to the concrete when delivered to provide proper moisture content (Photo 26). The RCCP was placed in two lanes of equal width to allow the vibratory roller to be on the RCCP at the proper time. The initial roller pass was made with the steel-wheeled vibratory roller in the static mode. After this initial pass, the RCCP was compacted with four passes of a vibratory roller. A final static pass was made to remove roller marks. During rolling, an observation was made that a rougher surface resulted when the vibratory roller was moving in reverse, thus it was operated in the vibratory mode only when moving forward. The vibrator was turned off a few feet before the forward motion was stopped to prevent a depression or bump at the end of a pass. A rubber-tired roller was applied about 5 min after the steel-wheeled vibratory roller finished, but its use was discontinued as it left noticeable ruts in the surface. These ruts were smoothed out with the steel-wheeled roller. A light layer (approximately 1/2 in.) of damp sand was spread over the surface after compaction to assist in curing.

35. Performance. The 6-in.-thick RCCP was in good condition after an estimated 2,100 tracked-vehicle passes. There were no visible signs of distress from daily traffic except for a small corner crack. Locked-track turns by an M-88 tank retriever caused no distress to this item (Photo 27).

Item F

36. Construction. The RCCP in Item F, was placed in one 10-in.-thick layer in a turn area of approximately 115 yd^2 (Figure 4). The concrete was discharged from the transit mixer directly onto the prepared base (Photo 28). The base was wetted prior to RCCP placement. A G-660 Gradall was used to spread the concrete prior to rolling. A heavy rain the night before the concrete placement resulted in a wet base (Photo 29). Prior to placing the RCCP, about 2 in. of saturated base material was removed from a section of the item, and the difference was made up with an additional 2 in. of RCCP (Photo 30). A

vertical edge along Item E was cut with the Gradall (Photo 31). A stringline was used to control grade and slope during construction (Photo 32). Final surface texture of Item F is shown in Photo 33.

37. Performance. The 10-in.-thick RCCP was in excellent condition after an estimated 2,100 tracked-vehicle passes. A minimal amount of wear has been observed on the inside radius edge where tracked vehicles drove across the corner; otherwise, no distress is evident.

Item H

38. Construction. Item H was placed in an intersection with an area of approximately 325 yd^2. The item was placed in one 10-in.-thick layer and formed a T-intersection between Items G, I, and L (Figure 1). The base was wetted before placement of the RCCP. The asphalt in Items G and L was cut back to expose a vertical face (Photo 34). The concrete was dumped directly from the transit mixer onto the prepared base. The item was constructed in two halves--one starting against Item G, the other starting against Item L--each joining along the center line of the main road. This was done because of the inability to maneuver both the Gradall transit mixer and roller within the working area. Approximately 1-1/2 gal of water was added to the concrete when delivered to provide proper moisture content. The RCCP was spread with a Gradall to an elevation maintained by grade stakes. Some hand work was required along the joints between this item and Items G and L (Photo 35). The construction procedure caused delays in rolling the RCCP against Item L; however, it appeared to compact as well as the other half. The dual-wheeled, single-drum vibratory roller made one static pass approximately 30 min after placement followed by four vibratory passes. The RCCP abutting Item L was rolled similarly except the initial static rolling was delayed by about 20 min. After rolling was completed, 2-ft-long dowels were driven at 18-in. spacings into the edge between this item and Item I (Photo 36). About 1/2 in. of wet sand was placed by shovel over the RCCP after the rolling was completed (Photo 37).

39. Performance. This 10-in.-thick RCCP intersection was in very good condition after an estimated 3,100 tracked-vehicle passes. A small shrinkage crack propagating from the cold joint of Item I through the center of Item H was the only sign of distress. The crack was approximately 1/16 in. wide and 22 ft long and was not spalling (Figure 4).

Item I

40. Construction. Item I was placed in an area approximately 86 by 25 ft, in one 8-in. thick layer, adjacent to Item H. During placement of this item and also Items J and K, the climate (cool temperatures, very humid, overcast skies) was ideal for RCCP construction. The base course was graded to final elevation and then wetted. The doweled cold joint adjoining Item H was cleaned and wetted prior to placement. This item was constructed in two paving lanes to accommodate all the equipment in the restricted working area (Photo 38). These lanes were alternately developed to prevent formation of a cold longitudinal joint. The concrete was dumped directly from the transit mixer onto the prepared base and then leveled with a Gradall. Hand shovels were used by the workers to place the concrete against existing items. Approximately 1-1/2 gal of water was added to the delivered concrete to achieve the desired consistency, giving the paste enough moisture for good compaction. Two passes of the roller in the static mode were made on the RCCP 15 min after placement (Photo 39). After these two passes, three passes each in alternating vibratory and static modes were made (Photo 40). The roller drum generally passed within 1 ft of the outside edge and worked its way toward the center by about three-fourths the width of the drum for each pass. The outside edges were rolled last. The total thickness was reduced by about 15 percent during the rolling process. The surface was then wetted with a hose and rolled a few minutes later with two more static passes to tighten the surface texture. Finally, approximately 1/2 in. of sand was applied using shovels and was wetted to facilitate curing.

41. Performance. This 8-in.-thick RCCP was in good condition after an estimated 1,300 tracked-vehicle passes. Locked-track turns by an M-88 tank retriever caused no distress to this item. At the time of inspection, a shrinkage crack approximately 3/16 in. wide ran through the middle of the item and was lightly spalled (Photo 41). The remainder of Item I exhibited no distress. Beam samples were cut from this item (Figure 5). Table 11 gives the results of the flexural strength tests performed on the samples. Test results indicate that the RCCP exceeds the flexural design strength requirements of 650 psi.

Item J

42. Construction. Item J was placed in an area approximately 62 by 25 ft, in one 6-in.-thick layer adjacent to Item I. The weather during

placement was ideal, consisting of cool temperatures, high humidity, and overcast skies. The concrete was placed directly on the wetted base from the transit mixers and spread with a Gradall. The transition from the 8-in.-thick Item I to the 6-in.-thick Item J was made within a transition of 5 ft. The item was constructed as in Item I, with two paving lanes alternately developed to allow for better equipment use in a confined area. Approximately 1-1/2 gal of water was added to the concrete when delivered to provide proper moisture content. A roller pattern similar to that of Item I was used with two static passes followed by three passes each of alternating vibratory and static mode rolling. The finished surface was covered with 1/2 in. of sand and wetted to cure the RCCP.

43. Performance. This 6-in.-thick RCCP was in good condition after an estimated 1,300 tracked-vehicle passes. Locked-track turns by an M-88 tank retriever caused no distress to this item. A shrinkage crack approximately 1/8 in. wide ran through the northern end of the item and was spalled lightly (Photo 42). The remainder of the item exhibited no distress. Two beam samples were cut from the item (Figure 5). The results of flexural strength tests performed on these samples are given in Table 11. Test results indicate that the RCCP exceeds the average flexural design strength requirement of 650 psi. The lower flexural strengths found in the bottom half of several of the pavement samples for Item J were from voids caused by either segregation during placement or inadequate compaction (rolling). These void areas were not widespread, but this type of deficiency may cause localized failure under traffic.

Item K

44. Construction. Item K was placed in an area approximately 24 by 25 ft, in one 4-in.-thick layer, between Item J and an existing conventional PCC pavement. The climate during placement was ideal, consisting of cool temperatures, high humidity, and overcast skies. The concrete was placed directly onto the wetted base from the transit mixers and spread with a Gradall. As with Item J, the transition from the 6-in.-thick Item J to this 4-in.-thick item was made within a transition of 5 ft. The RCCP was also placed with two paving lanes alternately developed to allow for better equipment use in a confined area. The end of the RCCP adjoining the existing PCC pavement was tapered on top of the sloped end of the existing pavement for approximately 5 ft to form a continuous road surface (Photo 43). Approximately 1-1/2 gal of

water was added to the concrete when delivered to provide proper moisture content. The roller pattern used was similar to that of Items I and J, with two static passes followed by three passes each of alternating vibratory and static mode rolling. The workers covered the finished surface with 1/2 in. of sand and wetted it to cure the RCCP.

45. Performance. This 4-in.-thick RCCP was in good condition after an estimated 1,300 tracked-vehicle passes. Locked-track turns by an M-88 tank retriever caused no distress to this item. At the connection between Item K and the existing concrete pavement, there was spalling and cracking. Samples were cut from the item (Figure 5). The results of flexural strength tests performed on these samples are given in Table 11. The test results indicate that the RCCP exceeded the flexural design strength requirements of 650 psi.

Item M

46. Construction. Item M was an existing RCCP test section, 10 in. thick, that had been in place for 2 years prior to the construction of this test section. It butts against Item L, which overlapped 45 deg at the slope edge of the RCCP. The construction procedures and mix requirements used to construct this item were the same as those used in the other RCCP items.

47. Performance. This 10-in.-thick RCCP was in good condition after an estimated 25,000 tracked-vehicle passes. Item M contained two cold joints that were spalling. The largest crack had spalled to about 2 in. wide and 1 in. deep.

Paving Blocks/Sand Grids, Item D

Description

48. Paving blocks have been manufactured from concrete, clay, and so forth in various sizes and designed for use as pavement surfaces. New types of materials and manufacturing techniques have improved the strength and durability of these surfaces. The paving blocks are usually shaped in such a way as to provide an interlock when placed. They can provide attractive geometric shapes and various color schemes that are often factors in choosing paving blocks. The blocks have an advantage over conventional pavement in that if one is damaged it can be easily replaced. This also aids in repairing utility cuts. Paving blocks require a strong base to prevent settlement. The base materials must meet grade and smoothness requirements before the blocks are

placed. The blocks are placed by hand, resulting in a labor-intensive construction procedure.

49. Sand-grid confinement is a new concept for pavement base course construction developed at WES (Webster 1986). The concept involves the confinement of sand or sandy materials in interconnected cellular elements called grids to produce a load-distributing pavement base layer. The grids have application as either a base for a pavement structure or a road surface. For road applications, a sand-asphalt surfacing is incorporated within the top portion of the sand-grid cells. Its function is to seal the sand into the cells and provide a wearing surface for moderate amounts of rubber-tired traffic. The sand-asphalt surfacing is formed by spraying a suitable liquid asphalt (emulsions or cutbacks) at a rate of approximately 1 gal/yd^2 on the surface of the sand-grid layer. Other pavement structures are normally installed over the sand-grid layer for high traffic volumes. When compared with other engineering alternatives, sand grids are relatively expensive to use for base courses. The chief advantage lies in their expedient use of otherwise unsuitable local materials for construction. The high-density polyethylene grid becomes more flexible in hot weather and stiffer at cold temperatures. The plastic contains carbon black for ultraviolet protection and is not damaged by sunlight during normal usage. For road applications across beach or desert sands, a sand-grid base course surfaced with an application of liquid asphalt sprayed on is capable of handling over 10,000 passes of heavy truck traffic including tandem axle loads up to 53,000 lbs. After filling the grids with sand or sandy material, compacation is obtained with a vibratory roller. Water is added as necessary for better compacation.

Design

50. In this study the paving-block/sand grid item measured 24 by 21 ft. The paving-block layer was approximately 2-1/2 in. thick. The sand grids were placed in one layer beneath the paving blocks and extended 4 ft beyond the road surface on both sides not bordered by Items C and E to provide the desired support for the paving blocks.

Paving blocks

51. The paving blocks used were "Uni-Stone," manufactured by Paver Systems, Inc., Rivera Beach, Florida. The blocks were made of concrete and, according to the manufacturer, a special pressure-vibration process was used during fabrication making them stronger than regular concrete. The blocks had

nominal dimensions--9 in. long, 4-1/2 in. wide, and 2-1/2 in thick.

Sand grids

52. Each grid section weighed 105 lb and consisted of 60 plastic strips, each 8 by 132 in. and 0.05 in. thick. These strips had ultrasonic welds every 13 in. and the grid expanded to form a honeycomb arrangement of 561 cells that covered an area of 8 by 20 ft.

Construction

53. Item D was constructed with one course of paving blocks over one layer of sand grids. To provide adequate drainage beneath this item, the base material and the clay subgrade were excavated approximately 3 ft to the natural sandy subgrade and backfilled with natural sand (Photo 44). This backfill was compacted with a minimum of eight passes of the vibratory roller and filled to within 1 ft of the final surface elevation (Photo 45). The grids were then placed directly on the sand surface. Workers used stringlines to help in placing the sand grids. Three workers on each side of the grid expanded the grid to its full 8- by 20-ft size, aligned it with the help of the stringline, and then filled some of the outside cells with sand to hold it in place (Photo 46). They then filled the grids with natural sand using a Gradall and spread the sand with shovels to a depth of approximately 1 in. over the grids (Photo 47). This process was continued until all the required grids were placed. The sand grids were compacted with eight passes of a vibratory roller. After compaction, the approximately 1-in.-thick sand layer was raked and leveled to a grade 3 in. below the final pavement surface (Photo 48). This loose sand surface allowed for final grade adjustments as the paving blocks were placed. Restraining timbers (4 by 8 in. by 24 ft), anchored with steel rods, were placed along the free edges on each side of the paving blocks (Photo 49). The workers placed the paving blocks by hand, one row at a time, in a herringbone pattern (Photo 50). The blocks were checked for proper grade as they were laid against the surrounding blocks and the stringline and adjusted accordingly. End pieces required along the edges were cut smoothly and efficiently by the workers using a hydraulic rock splitter (Photo 51). When all the blocks had been placed and both side restraining timbers were in place, the edge blocks were sealed with a sand-cement mixture to help seat and restrain the edge of the pavement (Photo 52). Using a shovel, workers spread a 1-in. layer of damp sand over the entire paving block area and used a hand-operated vibratory plate compactor to seat the blocks and

work the loose sand into the cracks between them (Photo 53). The remaining sand was later swept from the surface.

Performance

54. The paving blocks were in good condition and showed only minor distress after an estimated 2,100 tracked-vehicled passes. The locked-track turns made by an M-88 tank retriever caused no distress to this item (Photo 54). There was approximately 1/2 in. of settlement across the entire item, with additional rutting approximately 1/2 in. deep in the traffic lanes as a result of traffic (Photo 55).

Latex-Modified Asphalt Concrete, Item E

Description

55. Latex-modified asphalt is an asphalt with 3 to 5 percent rubber added. There are many types of rubber latex such as butyl, styrene-butadiene, acrylonitrile-butaine (nitrile), polyisobutylene, polybutadiene, chlorophrene, neoprene (Gannon and Majidzadeh 1972; Carey 1974). Latex is added to the asphalt to improve its quality. The physical changes are promoted to include greater flexibility and cracking resistance, increased stripping resistance, and increased durability of asphalt concrete. These modifiers may be added to the asphalt at the refinery or at some intermediate location before delivery to the asphalt mixing plant or they may be added at the plant. The latex must be stored to prevent damage from freezing. Latex-modified asphalt can be mixed and placed as a conventional asphalt mix. The mixing temperature may be higher or lower than with normal asphalt concrete, depending on the type of latex used.

Design

56. The latex-modified asphalt concrete item measured 92 by 21 ft and was placed in two 2-in. lifts. The asphalt was modified with a Polysar Latex 275, manufactured by Polysar Inc., Chattanooga, Tennessee. The Polysar Latex was added to the asphalt mix at the rate of 0.9 gal per ton of mix. The pavement structure was designed for high-pressure tires (tracked vehicles) in accordance with TM 5-822-5 (Department of the Army 1980). The actual properties of the asphalt mix, as constructed, are given in Table 13.

Construction

57. The asphalt was to be placed in two lifts; however, a breakdown in

the original paver required that a replacement paver be obtained. Because of the minimum time of availability of this replacement paver, a decision was made to pave all remaining asphalt items in one lift. This would allow for timely completion while satisfying density and grade requirements. The actual thickness of the asphalt placed in Item E varied from 4 to 5-1/2 in. This variation was necessary to achieve the proper grade. The asphalt concrete was placed in two lanes with a Cedar Rapids paver (Photo 56). The base surface received a prime coat prior to placing the first lift of asphalt concrete; however, it did receive some minor damage from traffic (pick-up and/or dirt tracked on the surface) before it was covered. Using a dual-diaphragm pump, workers added Polysar Latex at the plant from 55 gal drums (Photo 57). The mixing temperature was 350° F which was higher than normal because of the Latex additive. With the higher temperature required, the workers had to wait approximately 15 min before they could begin rolling. A 10-ton steel-wheeled vibratory roller was used for breakdown-and-finish rolling; whereas, a 20-ton-rubber-tired roller was used as the intermediate roller (Photo 58). Several passes of each roller were used. The final densities obtained in the pavement averaged 95.3 percent of laboratory density (Table 14). Figure 6 gives the locations of cores taken. The final mix contained a small amount of roots and sticks. These were caused by a contaminated sand stockpile containing roots, sticks, and a small amount of clay (Photo 59). The percentage of this deleterious material in the mixture was small and was only evidenced by a few roots and sticks in the final surface (Photo 60).

Performance

58. The Polysar Latex-modified asphalt concrete was in good condition after an estimated 1,300 tracked-vehicle passes. Locked-track turns by an M-88 tank retriever caused only minor pavement scuffing and a small tear to this item (Photo 61). The normal traffic pattern on this item, without turning, had caused no distress.

Georgia State E-Mix Asphalt Concrete, Item G

Description

59. The Georgia State E-Mix is the standard asphalt concrete mix used in this area as a surface mix by the Georgia Department of Transportation.

Design

60. Item G measured 65 by 22 ft and was placed in two 2-in. lifts. A standard Georgia E-Mix is a dense-graded mix for either intermediate or surface courses with a 3/4-in. maximum size aggregate. The pavement structure was designed for high-pressure tires (tracked vehicles) in accordance with TM 5-822-5 (Department of the Army 1980). The actual properties of the asphalt mix, as constructed, are given in Table 15.

Construction

61. A total of 4 in. of ashpalt in two equal lifts was to be placed in this item. However, mechnical problems encountered with the original paver caused uneven lift thicknesses resulting in final thickness variations of 4 to 5 in. over the entire item (Photo 62). A second paver was obtained the next day and used to complete this item and the two other asphalt items. The base course was primed prior to paving. The surface of the intermediate lift, after the first day, showed about 12 ft^2 of cracking on each edge of the pavement. The cracking did not appear to be a problem related directly to the asphalt; instead, it appeared to be alligator cracking. The asphalt was compacted with approximately four passes each of a dual-drum vibratory roller and a 20-ton rubber-tired roller. The cracks that developed at the intermediate lift showed up in the surface lift (Photo 63) The final densities obtained in the pavement averaged 94.4 percent of the laboratory density (Table 15). Figure 6 gives locations of the cores that were taken.

Performance

62. The standard Georgia State asphalt concrete was in good condition. It showed minimal signs of distress from traffic, except where locked-track turns were performed by the M-88 tank retriever (Photo 64). The pavement surface tore immediately upon the start of the turn; hence, the turn was not completed. The only other distress was from the alligator cracking developing during construction.

Steel-Slag Asphalt Concrete, Item L

Description

63. Steel-slag asphalt is asphalt concrete containing slag aggregate, a by-product of a smelting furnace process, usually steel ore. This type of asphalt mixture is limited by the availability of slag in the area.

Steel-slag asphalt can be mixed and placed with conventional asphalt equipment. A problem associated with this type of aggregate occurs because of the variations in specific gravity inherent in some slag aggregates. This variation can cause problems in controlling the void content of the mix.

Design

64. The steel-slag asphalt concrete item measured 57 by 22 ft and was placed in two 2-in. lifts. The steel slag made up approximately 50 percent by weight of the aggregate used in this mix. The slag asphalt mix was designed for high-pressure tires (tracked vehicles) (Department of the Army 1980). The acutal properties of the slag asphalt mix as constructed are given in Table 13.

Construction

65. A total of 4 in. of blast furnace steel-slag asphalt was placed in one lift because of the time constraints on an asphalt paver availability (see paragraph 57). Item L abutted an existing RCCP section, the edge of which was sloped at a 45-deg angle. This slope was broomed and tacked, and the base course was primed before the item was paved. The asphalt was compacted by several passes of a dual-drum vibratory roller along with a 20-ton rubber-tired roller. Approximately 15 ft^2 of the cracking appeared during rolling in the northeast corner of the item in both lifts (Photo 65). This alligator cracking was attributed to the underlying based course saturated the previous night by a rain storm. Figure 6 gives the locations where the cores were taken.

Performance

66. The blast furnace slag asphalt mix was in good condition. Locked-track turns by an M-88 tank retriever caused only pavement scuffing. Traffic caused no visible distress to this pavement (Photo 66). Alligator cracking in one corner was the only sign of distress.

PART IV: COST ANALYSIS

67. A complete cost analysis must include an analysis of the performance life of the various pavement types, which was beyond the scope of this report.

68. Actual cost comparisons from the test section construction are difficult because of the limited size of the test sections. A cost comparison between various surfacing materials is given in Table 16. Reinforced concrete and the State asphalt mix are used as standard references for cost because these are two types of surfaces commonly used.

69. Fiber-reinforced concrete and RCCP both have lower costs for material and labor, when compared with wire-mesh reinforced concrete; however, they both provide a rougher surface texture. Fiber-reinforced concrete will have a rough surface where there are exposed fibers and for RCCP the rough surface is produced by the method of construction.

70. In comparison with the standard Georgia E-Mix, latex-modified asphalt concrete had higher material and equipment cost that may be offset by an anticipated increase in pavement durability. The latex increases the viscosity of the asphalt, requiring higher mixing temperatures resulting in a higher fuel cost. Slag aggregate can have lower costs for material depending upon local availability of the aggregate. Paving blocks with sand grids as a base or another suitable base material will have higher lower costs for material, labor, and preparation. The equipment cost will be lower because the paving blocks are labor-intensive for placement. Paving blocks have an advantage of providing an abrasion-resistant surface and of being easily replaced or adjusted.

71. The costs of RCCP in various locations versus the next lowest cost paving option are given in the following tabulation.

Location	RCCP Cost $\$/yd^2$	Cost Savings of RCCP Over Alternative percent
Fort Hood, Texas	16.00	15*
Port of Tacoma, Washington	18.00	30*
Portland, Oregon	16.00	32**
Fort Stewart, Georgia	21.00	--

* Alternative was reinforced PCC pavement.
** Alternative was asphalt cement pavememt.

PART V: SUMMARY AND CONCLUSIONS

Current Performance

72. This study investigated the cost effectiveness of asphalt concrete pavements at several military installations (Fort Bliss, Fort Hood, Fort Stewart, and Detroit Arsenal) that have been in place for varying periods of time and have received varying amounts of tank traffic. The pavement at Detroit Arsenal was constructed in accordance with the Corps of Engineers (CE) recommended specification for tank roads. The roads at the other installations investigated were constructed with mixes prepared according to State specifications. Analysis of the various mixes shows that the Detroit pavement has fewer fines and more voids total mix than the other three pavements (Tables 2, 4, 6, and 7). The Detroit mix also has a larger size maximum aggregate (3/4 in.). No direct correlations can be made between pavement performance and mix content because of the asphalt mix and traffic variations. The pavement at the Detroit Arsenal is performing well, although the volume of tracked-vehicle traffic is very low. The pavements at the three other locations receive a higher volume of traffic; however, all mixes perform similarly.

73. The pavements at Fort Bliss and Fort Hood were constructed in accordance with the Texas State specifications. However, differences in local aggregates, contractors, and procedures make it difficult to accurately compare the two pavements. Personnel at Fort Bliss were not satisified with the performance of their asphalt concrete pavements and were replacing them with PCC, wherever possible. At Fort Hood, they were satisfied with asphalt pavements. The pavement performance at each base was similar; the differences were in perception. At Fort Bliss, concrete has been used at intersections because of the relatively faster erosion of asphalt; however, at Fort Hood, the same problems exist, but it is felt that repairs to asphalt are easier than working with concrete pavement when it wears down or erodes from trafficking.

74. The use of the CE-approved specification is required for pavement construction for tank roads. However, in many cases, lower costs along with local experience with State-specified surface asphalt concrete mix result in their usage instead of the CE-specified mix. This can result in reduced

durability and wear of the mix and therefore requires more frequent repairs, resulting in increased costs.

Field Performance, Fort Stewart

75. The effects of traffic on the test section, especially Items F, G, H, and L, have been tempered because of the amount of soil that has been dumped and washed onto these items. Because of the improper grading of the shoulders, an average of 2 to 3 in. of soil covers most of these items (Photo 67). Although this soil protects the pavement surface, it also allows the soil to be carried onto maintenance areas, requiring additional cleaning.

Reinforced Concrete

76. The fiber-reinforced concrete of Item A has performed well. The addition of the fibers to the concrete caused no construction problems.

77. The wire-mesh-reinforced concrete of Item B has performed well, with only a few random hairline surface cracks appearing.

RCCP

78. The RCCP in Items C, F, H, I, J, K, and M has performed well in all. These items consisted of RCCP varying from 4 to 10 in. thick. The surface of these items was satisfactory for all traffic. Large areas have developed temperature cracks that will eventually open and spall. The joints between items and noncontinuous placements have also suffered minor spalling.

Paving Blocks

79. The concrete paving blocks of Item D have performed well, despite rutting in the traffic lanes. The rutting and overall settlement of the item was caused by consolidation of the sand and sand-grid base. An advantage of the paving-block system is that any deficient area can be corrected by removing the blocks and repairing the underlying problem.

Asphalt Concrete

80. The asphalt concrete in Items E, G, and L has performed well in all. The cracks developing in these items during construction (compaction of the asphalt mix) were caused by localized base failures because of excessive moisture in the underlying base course. The low densities obtained were caused by the combination of equipment problems, maneuverability restraints throughout all asphalt concrete items, and the small volume of material placed (Table 14 and 15). The scuffing of Item E occurring during locked-track tests

was partially attributed to the fact that this item had the lowest average density of all the asphalt items. This was placed first and had construction delays caused by breakdown of the paver.

PART VI: RECOMMENDATIONS

81. Use fibrous concrete in pavement construction for tracked vehicles. The minimum thickness should be 2 in. It should also satisfy structural design requirements.

82. Investigate further the use of concrete paving blocks with various base materials prior to full-scale use. The distress in the paving block item of this study was directly related to settlement of the sand-grid base course. Paving blocks have potential as surfaces for parking or maintenance areas and for roads.

83. Use RCCP for tracked-vehicle traffic. The optimum thickness will depend on the amount of traffic and the strength of the underlying surface. In many cases, RCCP can be placed directly on the existing grade surface. Shrinkage cracks forming in the RCCP surface may require periodic maintenance. This maintenance should be no more severe than that normally associated with conventional concrete pavements.

84. Evaluate, using a detailed field test, the performance of existing asphalt concrete pavements modified with latex rubber. These pavements should meet all specification requirements for density, gradation, asphalt content, and other pertinent mix requirements. These requirements are difficult to meet in small test sections where adjustments to the asphalt concrete mixture or construction procedures for correction of problems are not possible because of the small amount of material placed.

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Table 1

Core Data From Fort Bliss, Texas

Speciman No.	Location Street Name and Nearby Landmarks	Layer	Thickness in.	Specific Gravity	Density pcf
A1	Northbound lane Chaffee Rd., across from Bldg. 2651	1	1.2	2.489	155.30
		2	1.0	2.379	148.47
		3	1.8	2.379	148.47
A2		1	1.0	2.434	151.90
		2	1.0	2.346	146.40
		3	1.4	2.346	146.40
A3		1	1.3	2.459	153.56
		2	1.0	2.363	147.44
		3	1.5	2.369	147.44
A4		1	1.1	2.490	155.38
		2	1.0	2.507	156.43
		3	1.2	2.507	156.43
A5		1	1.0	2.440	152.24
		2	1.0	2.512	156.73
		3	1.5	2.512	156.73
A6		1	1.0	2.476	154.49
		2	1.0	2.493	155.59
		3	1.2	2.493	155.59
B1	Westbound lane Stennis St., across from Bldg. 2932	1	Damaged		
		2	1.2	2.422	151.14
B2	Westbound lane Stennis St., across from Bldg. 2932	1	2.0	2.453	153.04
		2	1.9	2.430	151.64
B3	Westbound lane Stennis St., across from Bldg. 2932	1	1.6	3.469	154.06
		2	2.6	2.440	152.24
B4	Across from Bldg. 2942	1	1.8	2.481	154.81
		2	2.5	2.440	152.27
B5	Across from Bldg. 2942	1	1.8	2.476	154.52
		2	2.0	2.420	151.02

(Continued)

Table 1 (Concluded)

Speciman No.	Location Street Name and Nearby Landmark	Layer	Thickness in.	Specific Gravity	Density pcf
B6	Across from Bldg. 2942	1	2.0	2.471	154.18
		2	2.2	2.420	150.98
C1	Eastbound lane Haan Rd., east of Harmon Rd	1	1.5	2.414	150.63
C2		1	2.3	2.515	156.94
		2	1.0	2.431	151.69
C3		1	1.5	2.379	148.45
		2	1.0	2.389	149.05
C4		1	1.7	2.398	149.60
		2	1.0	2.362	147.37
C5		1	1.6	2.387	148.95
		2	1.0	2.371	147.95
C6		1	1.7	2.422	151.15
		2	1.0	2.323	144.97

Table 2

Bituminous Mix Analysis, Fort Bliss, Texas

	Cores* A1-A6		Cores B1-B6		Cores C1-C6	
	Field Cores 6-in. diam	Not Enough Material for Compaction	Field Cores 6-in. diam	Recompacted Cores 4-in. diam	Field Cores 6-in. diam	Recompacted Cores 4-in. diam
Size of sieve						
1 in.						
3/4 in.			100.0		100.0	
1/2 in.	100.0		87.0		98.8	
3/8 in.	99.3		73.6		94.1	
No. 4	74.7		57.7		66.5	
No. 8	45.9		48.7		44.7	
No. 16	30.0		39.8		24.9	
No. 30	21.4		32.5		15.8	
No. 50	16.2		24.4		11.5	
No. 100	12.3		14.0		8.5	
No. 200	9.3		8.5		6.3	
Percent bitumen	5.4		5.0		5.4	
Grade bitumen	--		--		--	
Marshall stability, lb	--		--	3,402	--	3,258
Flow 0.01 in.	--		--	16	--	22
Percent voids total mix	1.9		2.9	2.1	3.6	1.2
Percent voids filled	87.4		80.9	85.4	78.0	91.6
Density (field), pcf	153.8		155.3		151.0	
Theo density (lab), pcf	--			154.1		154.7
Thickness of field cores	1.1		1.6		1.7	
Percent lab density (field)	--		100.8		97.6	
Aggregate, specific gravity	2.74		2.76		2.74	
Aggregate, percent water absorption	0.70		0.68		0.70	
Penetration	31		31		21	
Viscosity						
140° F (poises)	5,574		8,409		33,050	
225° F (centistokes)	2,380		3,307		6,403	
275° F (centistokes)	438.2		520		747.2	

* Analysis on top layer of each core only.

Table 3

Core Data From Fort Hood, Texas

Speciman No.	Location Street Name and Nearby Landmarks	Layer	Thickness in.	Specific Gravity	Density pcf
A1	Westbound lane North Ave. across from hardstands at Bldg. 9127	1	2.0	2.360	47.28
		2	1.3	2.393	149.31
		3	2.5	2.429	151.58
A2	Westbound lane North Ave across from hardstands at Bldg. 9127	1	2.0	2.352	146.78
		2	1.0	2.427	151.43
		3	2.8	2.427	151.43
A3	Westbound lane North Ave across from hardstands at Bldg. 9127	1	2.0	2.331	145.48
		2	1.0	2.400	149.79
		3	2.0	2.404	150.01
B1	Across from Bldg. 9112	1	1.8	2.364	147.54
		2	1.5	2.396	149.52
		3	1.6	2.427	151.43
		4	1.6	2.362	147.36
		5	1.6	2.325	145.09
B2	Across from Bldg. 9112	1	1.5	2.343	146.23
		2	1.7	2.393	149.31
		3	1.7	2.435	151.95
		4	1.7	2.336	145.79
B3	Across from Bldg. 9112	1	1.5	2.345	146.33
		2	1.8	2.390	149.15
		3	1.7	2.433	151.84
		4	1.5	2.336	145.76
C1	Across from Bldg. 1919	1	1.5	2.290	142.92
		2	1.5	2.376	148.28
		3	1.6	2.398	149.66
		4	1.7	2.495	155.72
		5	2.2	2.453	153.10

(Continued)

Table 3 (Concluded)

Speciman No.	Location Street Name and Nearby Landmarks	Layer	Thickness in.	Specific Gravity	Density pcf
C2	Across from	1	1.5	2.273	141.86
	Bldg 1919	2	1.5	2.392	149.27
		3	1.7	2.411	150.47
		4	1.9	2.482	154.86
		5	1.5	2.445	152.56
C3	Across from	1	1.5	2.299	143.43
	Bldg. 1919	2	2.0	2.385	148.82
		3	2.4	2.403	149.89
D1	Southbound lane	1	1.8	2.317	144.59
	72nd St.	2	1.5	2.402	149.87
	nearby	3	1.4	2.396	149.53
	Bldg. 32014	4	1.0	2.48	155.15
D2	Southbound lane	1	1.7	2.380	148.49
	72nd St.	2	1.5	2.400	149.76
	nearby	3	1.2	2.491	155.42
	Bldg. 32014	4	1.1	2.384	148.78
D3	Southland lane	1	1.6	2.379	148.44
	72nd St.	2	1.3	2.383	148.72
	nearby	3	1.5	2.486	155.15
	Bldg. 32014	4	1.2	2.375	148.19
E1	Southbound lane	1	2.0	2.391	149.22
	S. 72nd St.	2	1.8	2.423	151.20
	nearby	3	1.7	2.480	154.78
	Bldg. 4448	4	0.9	2.350	146.62
E2	Southbound lane	1	1.8	2.385	148.84
	S. 72nd St.	2	2.0	2.372	148.01
	nearby	3	1.7	2.495	155.70
	Bldg. 4448	4	1.0	2.361	147.32
E3	Southbound lane	1	2.0	2.395	149.45
	S. 72nd St.	2	1.9	2.378	148.38
	nearby	3	1.7	2.494	155.63
	Bldg. 4448	4	0.9	2.368	147.79

Table 4

Bituminous Mix Analysis, Fort Hood, Texas

	Cores* A - E	
	Field Cores 6-in. diam	Recompacted Cores 4-in. diam
Size of sieve		
1 in.		
3/4 in.	100.0	
1/2 in.	94.7	
3/8 in.	87.1	
No. 4	63.5	
No. 8	43.8	
No. 16	36.5	
No. 30	32.3	
No. 50	27.0	
No. 100	16.8	
No. 200	10.4	
Percent bitumen	5.0	
Grade bitumen	--	
Marshall stability, lb	--	4,937
Flow, 0.01 in.	--	13
Percent voids total mix	3.0	1.4
Percent voids filled	79.0	88.9
Density (field), pcf	146.5	
Theo density (lab), pcf		148.8
Thickness of field cores	1.7	
Percent lab density (field)	98.5	
Aggregate, specific gravity	2.60	
Aggregate, percent water absorption	0.79	
Penetration	22	
Viscosity		
140° F (poises)	5,946	
225° F (centistokes)	3,250	
275° F (centistokes)	480	

* Analysis on top layer of each core only.

Table 5

Core Data From Fort Stewart, Georgia

Speciman No.	Location Street Name and Nearby Landmarks	Layer	Thickness in.	Specific Gravity	Density pcf
A1	The four sampling areas were equally spaced along McFarland St.	1	0.5	2.276	142.00
		2	0.5	2.276	142.00
		3	1.5	2.380	148.51
A2		1	0.7	2.268	141.52
		2	0.5	2.268	141.52
		3	1.5	2.403	149.96
A3		1	0.5	2.273	141.84
		2	0.6	2.273	141.84
		3	1.5	2.388	149.02
A4		1	0.7	2.245	140.09
		2	0.5	2.245	140.09
		3	1.4	2.410	150.37
B1		1	0.5	2.220	138.51
		2	0.6	2.220	138.51
		3	1.5	2.383	148.70
B2		1	0.6	2.268	141.55
		2	0.5	2.268	141.55
		3	1.5	2.382	148.63
B3		1	0.5	2.276	142.02
		2	0.5	2.276	142.02
		3	1.4	2.404	150.03
B4		1	0.5	2.252	140.51
		2	0.5	2.252	140.51
		3	1.5	2.388	149.01
C1		1	0.6	2.301	143.61
		2	0.6	2.301	143.61
		3	1.5	2.389	149.09
C2		1	0.6	2.305	143.83
		2	0.5	2.305	143.83
		3	1.5	2.392	149.24
C3		1	0.6	2.309	144.09
		2	0.5	2.309	144.09
		3	1.5	3.388	149.02

(Continued)

Table 5 (Concluded)

Speciman No.	Location Street Name and Nearby Landmarks	Layer	Thickness in.	Specific Gravity	Density pcf
C4	The four sampling areas were equally spaced along McFarland St.	1	0.6	2.302	143.63
		2	0.5	2.302	143.63
		3	1.5	1.647	102.80
D1		1	0.7	2.272	141.79
		2	0.5	2.272	141.79
		3	1.5	2.395	149.43
D2		1	0.7	2.300	143.52
		2	0.5	2.300	143.52
D3		1	0.6	2.293	143.08
		2	0.5	2.293	143.08
		3	1.7	2.407	150.20
D4		1	0.5	2.282	142.41
		2	0.5	2.282	142.41
		3	1.8	2.406	150.10

Table 6

Bituminous Mix Analysis, Fort Stewart, Georgia

	Cores* A - D Field Cores 6-in. diam	Recompacted Cores 4-in. diam
Size of sieve		
1 in.		
3/4 in.	100.0	
1/2 in.	99.5	
3/8 in.	97.5	
No. 4	82.4	
No. 8	59.2	
No. 16	44.2	
No. 30	34.5	
No. 50	25.6	
No. 100	16.5	
No. 200	9.0	
Percent bitumen	6.0	
Grade bitumen	--	
Marshall stability, lb	--	
Flow, 0.01 in.	--	
Percent voids total mix	--	
Percent voids filled	--	
Density (field), pcf	**	**
Theo density (lab), pcf	--	
Thickness of field cores	0.6	
Percent lab density (field)	--	
Aggregate specific gravity	2.69	
Aggregate percent water absorption	0.4	
Penetration	13	
Viscosity		
140° F (poises)	434,130	
225° F (centistokes)	50,450	
275° F (centistokes)	46.3	

* Analysis on top layer of each core only.

** The top lift was too thin to provide enough material for density testing or recompcations.

Table 7

Two Bituminous Mix Analyses, Detroit Arsenal, Michigan

(Average Test Results Excluding Test Strip for 2-in. Overlay of Tank Roads)

	Specified Limit*	Job Mix Formula**	Average of Tests
Sieve size			
3/4 in.	100-100	100	100
1/2 in.	82-96	95	95.4
3/8 in.	75-89	86	85.7
No. 4	59-73	70	68.9
No. 8	46-60	56	55.0
No. 16	34-48	42	40.3
No. 30	24-38	28	28.1
No. 50	15-27	17	17.8
No. 100	8-18	8	9.8
No. 200	3-6	4	5.8
Percent bitumen	--	6	5.8
Marshall stability, lb	1,800 minimum	2,800	2,890
Flow, 0.01 in.	16 maximum	8	10
Percent voids* total mix	3-5	5.1	5.4
Percent voids* filled with asphalt	70-80	75	73
Laboratory density, pcf	--	--	164.8
Field density, percent of laboratory density	98 minimum	98.5 (test strip)	95.0

* Variation in the slag required the void calculations to be based on estimated specific gravities.

** Based on data from test strips placed on 16 August 1980. Original mix design was voided by a change from submitted materials.

Table 8

Results of Subgrade In Situ Field Test

Test No.	In Situ (Field) Depth ft	Moisture* percent	Dry Density pcf	Plate Bearing Test Depth ft	K** pci	California Bearing Ratio† Depth ft	CBR Value
PB-1	0.5	9.0	125.2	0.5	240	--	--
	0.8	9.2	120.4				
PB-2	0.5	7.3	124.3	0.5	320	--	--
	0.8	7.4	125.8				
CBR-3	0.5	10.6	120.4	--	--	0.5	16
	0.8	9.7	118.0			0.5	15
						0.5	13

* Density and moisture tests were made after a hard rain.
** Seating load for plate bearing tests was 2 psi.
† Surcharge weight for field CBR was 30 lb.

Table 9

Results of Laboratory Tests on CBR-3 Test Hole

Location	Hole No	Depth ft	Specific Gravity	USCS Classification†	Amount Passing No. 200 Sieve Percent	Maximum Density, pcf
Fort Stewart*	CBR-3	0.5	2.65	SM (Brown silty sand)	26	122**

* Fort Stewart, Georgia, 5th Battalion, 32nd Armory Motor Pool.
** At 8.6 percent optimum water content (CE-55).
† Unified Soil Classification System.

Table 10

Aggregate Gradation Used In All Portland Cement Concrete Items At Fort Stewart, Georgia

Sieve Size	Percent Passing		
	Coarse Aggregate*	Fine Aggregate	Blended Aggregate** Gradation
1-1/2 in.	100		100
1 in.	95		97.1
3/4 in.	71		83.1
1/2 in.	31		59.7
3/8 in.	11	100	48.1
No. 4	2	99	42.4
No. 8		96	39.9
No. 16		86	35.8
No. 30		57	23.7
No. 50		20	8.3
No. 100		4	1.7
No. 200		1	0.4

* Coarse aggregate (granite) conforms to ASTM D448, No. 57 gradation.

** Blend developed from plant stockpile gradations with 58.4 percent coarse and 41.6 percent fine aggregate.

Table 11

Flexural Strength Test Results, Fort Stewart

Roller-Compacted Concrete Pavement*

Beam and Sample No.	Length in.	Width in.	Depth in.	Maximum Load lb	Flexural Strength psi	Remarks	Average Flexural Strength at Beam** psi	Density Top/Bottom pcf
A1-1	7.5	2.5	2.5	1,577	757			
2	7.5	2.5	2.5	1,120	538			
3†	7.5	2.5	2.5	985	473	Voids		
4†	7.5	2.5	2.5	1,204	578		586	156.1/154.2
A2-1	9.0	3.0	3.0	2,173	724			
2	9.0	3.0	3.0	2,331	777		751	150.5/--
I1-1	18.0	6.0	6.0	9,420	785			
2	18.0	6.0	5.75	8,700	789			
3	18.0	5.5	5.5	8,040	933	Irregular		
4	18.0	5.0	5.5	6,640	790	Irregular	824	157.3/--
J1-1	18.0	5.0	5.0	6,120	881			
2	18.0	4.0	3.25	4,480	1,909			
3	9.0	3.0	3.0	2,275	758			
4				2,500	833			
5				2,170	723			
6				3,117	1,039			
7				2,130	710			
8				2,329	776			
9†				507	169	Coarse		
10†				544	181	Coarse		
11†				2,290	763			
12†				758	253	Coarse		
13	12.0	4.0	3.5	2,277	558	Irregular		
14	12.0	4.0	3.5	2,116	518	Irregular		
15	12.0	4.0	3.25	2,524	717		798	161.7/153
J2-1	18.0	6.0	6.0	11,800	983			
2	12.0	4.0	3.0	5,081	1,694	Tapered	1,340	156.7/--
K1-1	18.0	5.0	5.0	6,160	887			
2	18.0	5.0	5.0	7,100	1,022		955	153.6/--
K2-1	10.5	3.5	3.5	1,637	401	Coarse		
2	10.5	3.5	3.5	3,829	938			
3	10.5	3.5	3.5	4,222	1,034			

* CRD-C-16 method of test for flexural strength of concrete (using simple beam with third-point loading).

** All beams included in average.

† Bottom of beam sample.

Table 12

Roller-Compacted Concrete Pavement Mix Proportions

Material	Saturated Surface Dry Batch Weight (lb/yd^3)
Coarse aggregate	1,947
Fine aggregate	1,388
Cement	634
Water	209

Note: W/C = 0.33, 1 percent assumed air content.

Table 13

Bituminous Mix Analysis of Two Pavement Items Placed At Fort Stewart*

	Specified Limit**	Polysar Latex Modified Asphalt†	Steel-Slag Asphalt
Size of sieve			
3/4 in.	100	100	100
1/2 in.	82-96	98.5	98.5
3/8 in.	75-89	83.5	87.8
No. 4	59-73	59.5	58.0
No. 8	46-60	48.0	56.0
No. 16	34-48	40.8	42.3
No. 30	25-38	34.2	36.2
No. 50	15-27	24.2	26.4
No. 100	8-18	11.5	13.3
No. 200	3-6	5.6	6.8
Percent bitumen		5.6	5.9
Marshall stability, lb	1,800 minimum	4,020.0	4,173
Flow, 0.01 in.	16 maximum	12	14
Percent voids total mix	3-5	2.2	3.2
Percent voids filled	70-80	85.2	80.5
Laboratory density, pcf		141.5	153.0
Density, pcf		148.2	145.9
Density (percent of laboratory density)	98 minimum	97.8	95.4
Penetration of recovered asphalt concrete		39	36
Aggregate, specific gravity		2.64	2.67

* Analysis was made on representative mixture obtained during construction.
** Specified units from TM 5-822-8.
† Latex added at a rate of 0.9 gal per ton of mix.

Table 14

Results Of Field Cores On Bituminous Pavement Items

Fort Stewart, Georgia

Item and Speciman No.	Thickness in.	Unit Weight pcf	Percent Density*
E1	6	142.4	96.1
E2	3	141.5	95.5
E3	2-1/2	139.8	94.3
			Average 95.3
G1	4-1/4	138.9	93.1
G2	4-3/4	139.5	93.5
G3	4	140.8	94.4
			Average 93.7
L1	4-1/4	138.8	95.1
L2	4-1/2	138.1	94.7
L3	4-1/2	139.9	95.9
			Average 95.2

* Based on laboratory density, see Tables 13 and 15.

Table 15

Bituminous Mix Analysis of State of Georgia

E-Mix and Specified Limits*

	Specified Limits	Actual
Size of sieve		
3/4 in.	100	100
1/2 in.	85-100	98.3
3/8 in	70-85	88.7
No. 4	70-85	68.0
No. 8	44-48	56.0
No. 16	--	47.7
No. 30	--	40.2
No. 50	10-25	29.1
No. 100	--	15.3
No. 200	4-7	8.0
Percent bitumen	5-7	5.6
Marshall stability, lb	1,500 minimum	3,440
Flow, 0.01 in.	8-16	14
Percent voids total mix	4-5	2.5
Percent voids filled	70-82	83.7
Laboratory density, pcf	--	150.4
Density, pcf	--	149.2
Density (percent of lab density)	97.5 minimum	99.2
Penetration of recovered asphalt concrete	--	38
Aggregate, specific gravity	--	2.63

* Analysis was made on representative mixture obtained during construction.

Table 16

Cost Comparison Between Various Surfacing Materials*

Material	Material Costs	Labor Costs	Equipment Costs	Construction Preparation Costs**	Advantages	Disadvantages
Wire-mesh reinforced concrete	$58/yd^2 †	Standard Reference	Standard Reference	Standard Reference		
Roller-compacted concrete	$21/yd^2 †	Lower	Lower	Lower	Forms not required	Surface texture will vary and tend to be not as smooth
Fiber-reinforced concrete	$0.72/yd^2 ††	Lower	Equal	Equal	Increased strength without having to place reinforcing	Rough surface where fibers are exposed
Georgia E-Mix asphalt cement	Standard Reference	Standard Reference	Standard Reference	Standard Reference		
Latex-modified asphalt cement	Higher	Equal	Higher	Equal	Increased durability‡	Increase asphalt viscosity requires increased mixing temperature
Slag-aggregate asphalt cement	Equal/ lower‡‡	Equal	Equal	Equal	Inexpensive high quality aggregate	Limited geographic availability
Paving Blocks/ sand grids	$23.22 per ft^2**/ $11.25 per yd^2	Higher	Lower	Higher	Abrasion-resistant surface easily replaceable or adjustable	Labor-intensive during replacement

* The comparisons in the table are between wire-meshed-reinforced concrete and conventional asphalt versus the remaining surfacing materials.
** Construction preparation costs include base preparation, placing forms, and grade controls.
† Actual costs for completed item including material, labor, equipment, and preparation costs.
†† Material costs only.
‡ The addition of latex is intended to increase the durability of the asphalt pavement.
‡‡ Dependent on local availability.

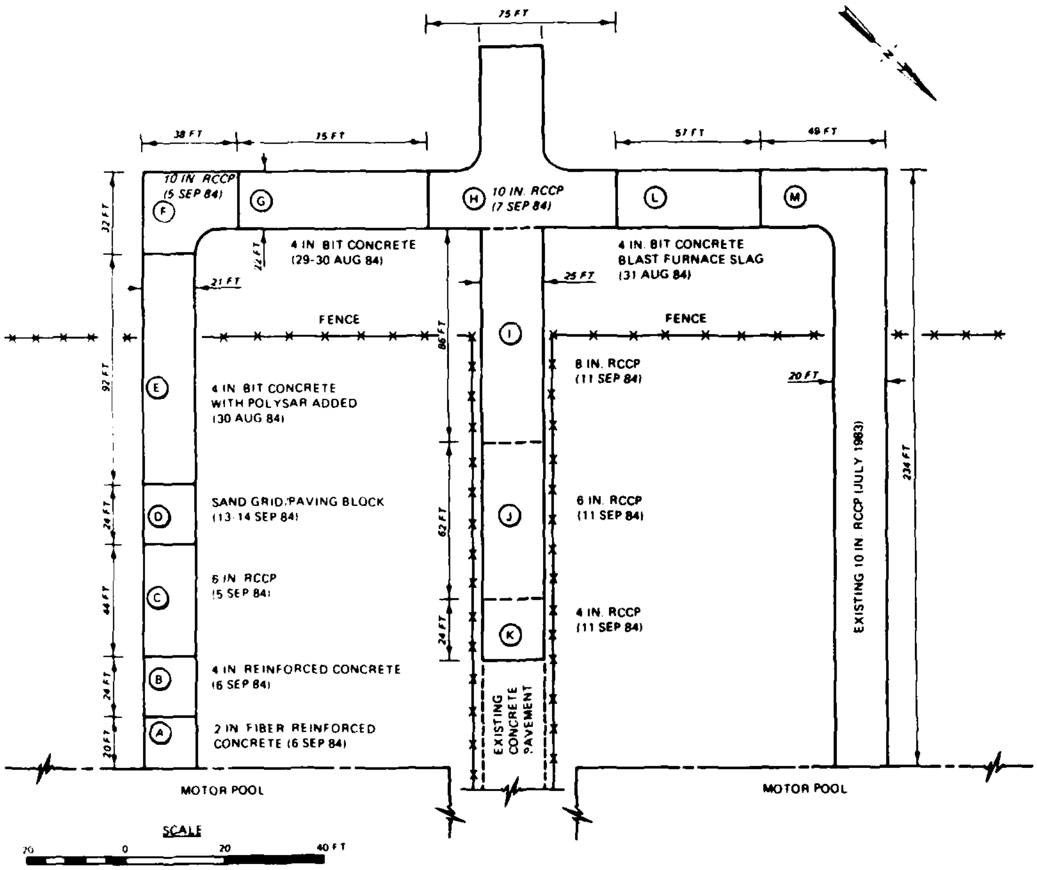
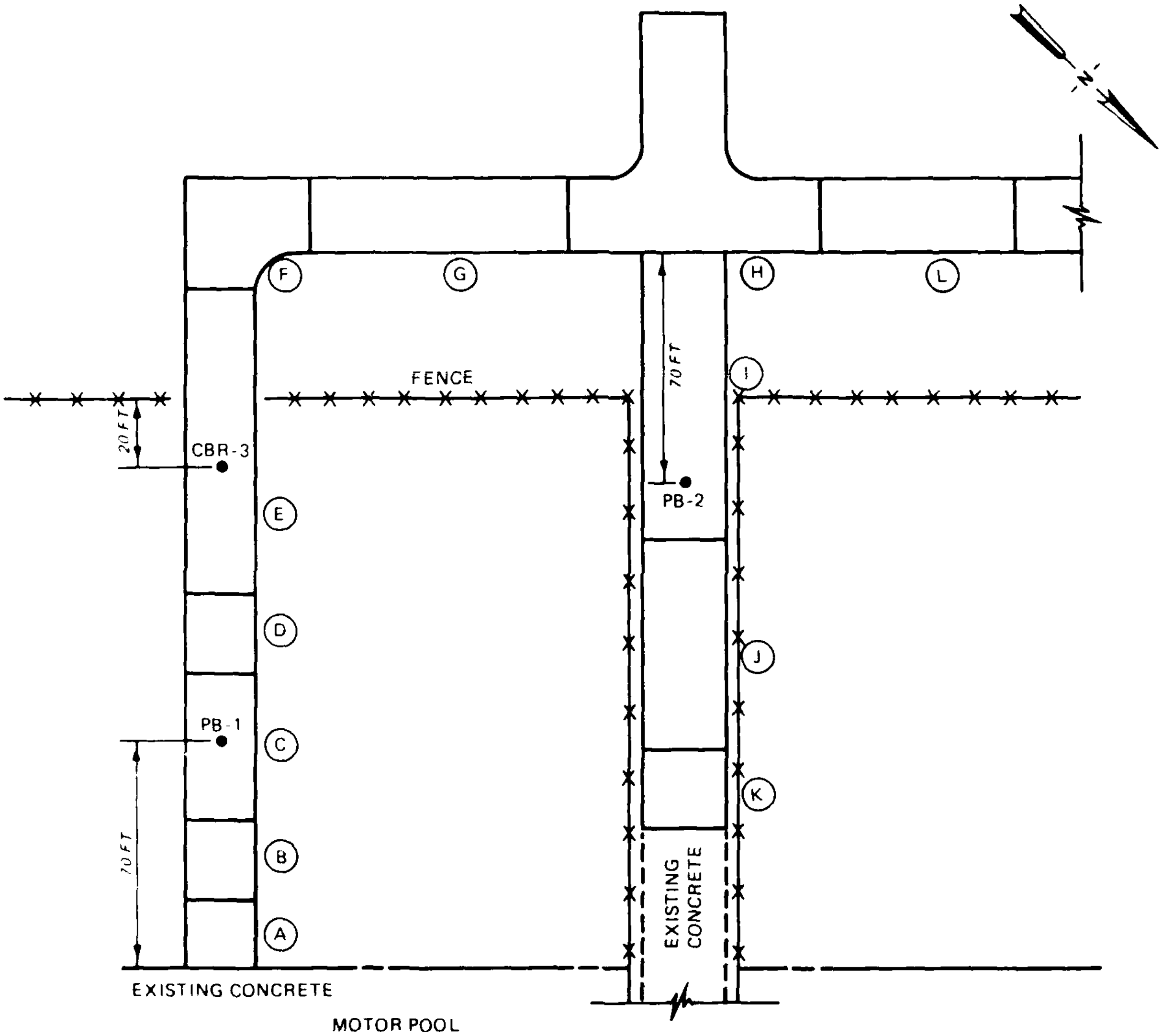
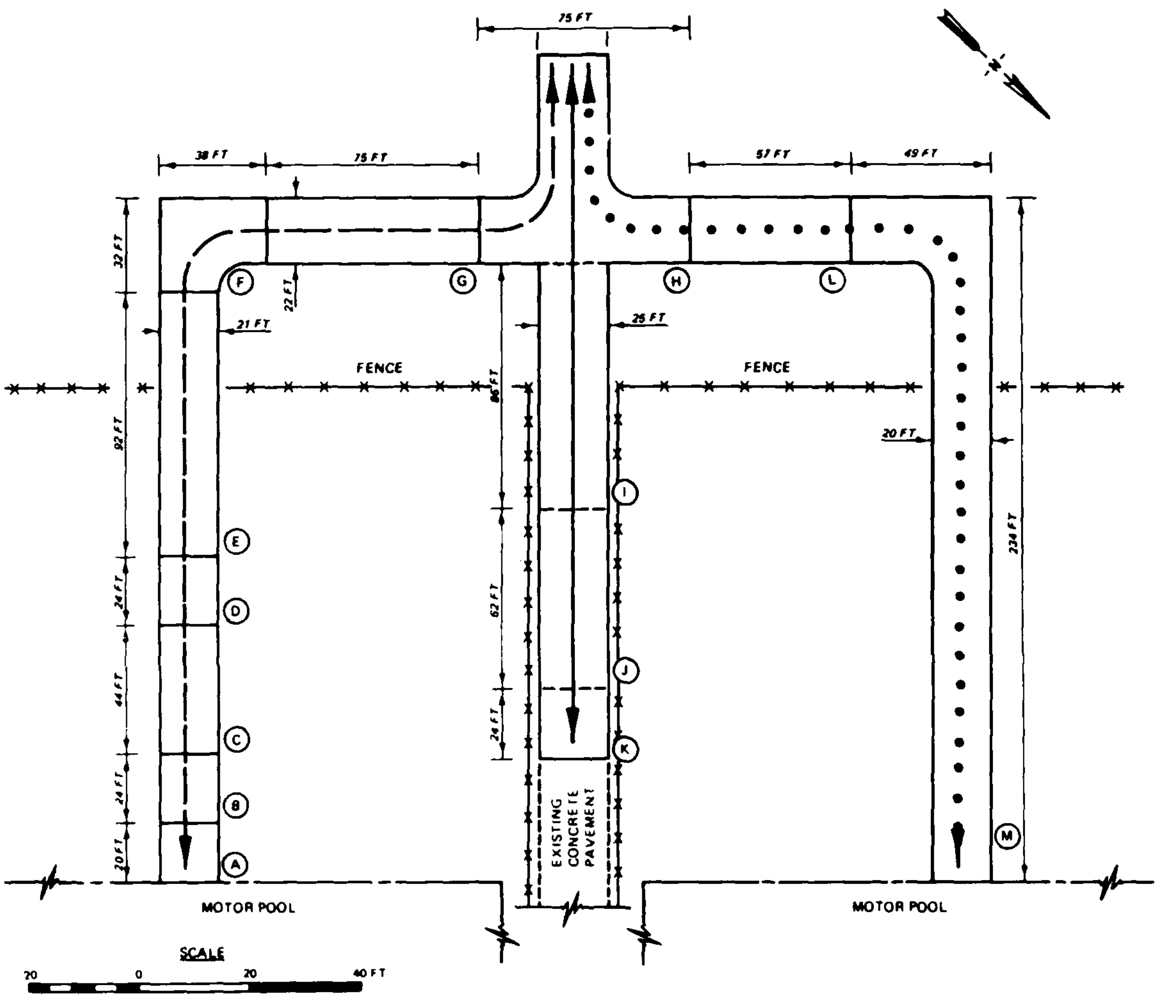


Figure 1. Layout of test items at Fort Stewart, Georgia



NOTE CIRCLED LETTERS DELINEATE TEST ITEM LOCATIONS

Figure 2. Location of in situ field test sites



ROUTES USED	APPROXIMATE PASSES PER WEEK M88	APPROXIMATE PASSES PER WEEK ALL TRACKED VEHICLES
I — —	32	64
II ———	20	40
III • • • •	90	180

Figure 3. Estimates of tracked-vehicle passes on Fort Stewart test section

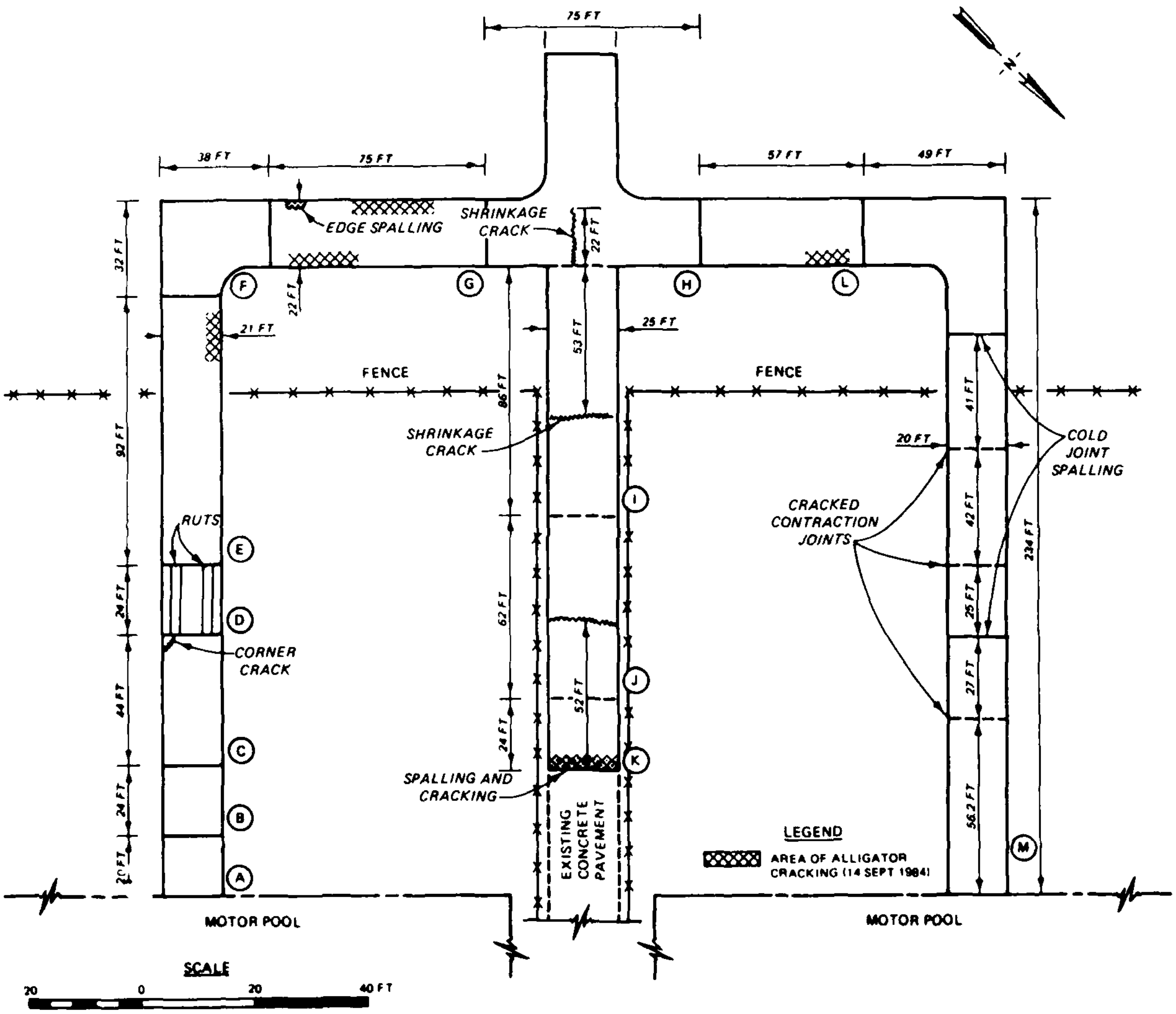


Figure 4. Location and type of pavement distress, Fort Stewart, Georgia, 8 May 1985

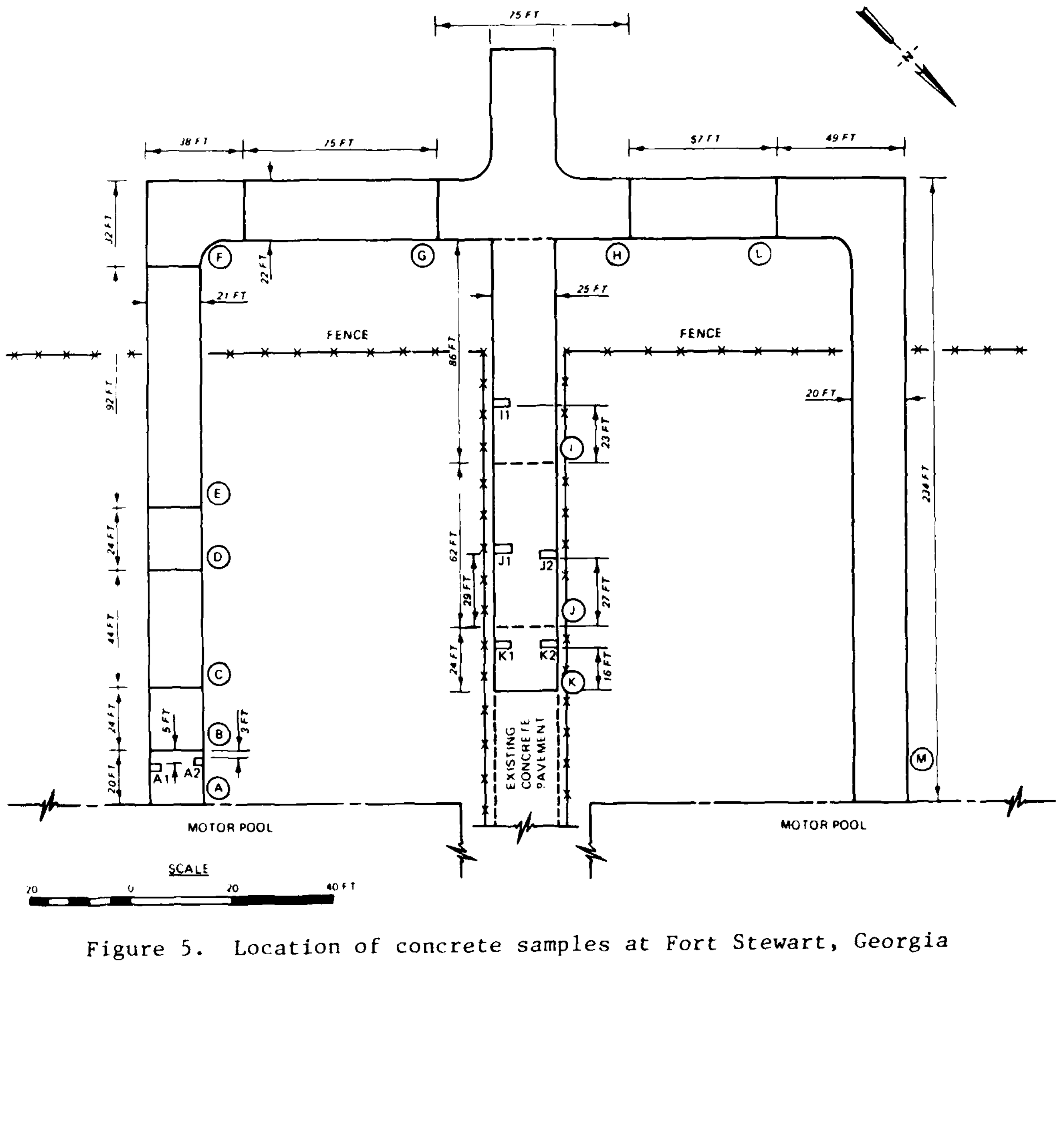
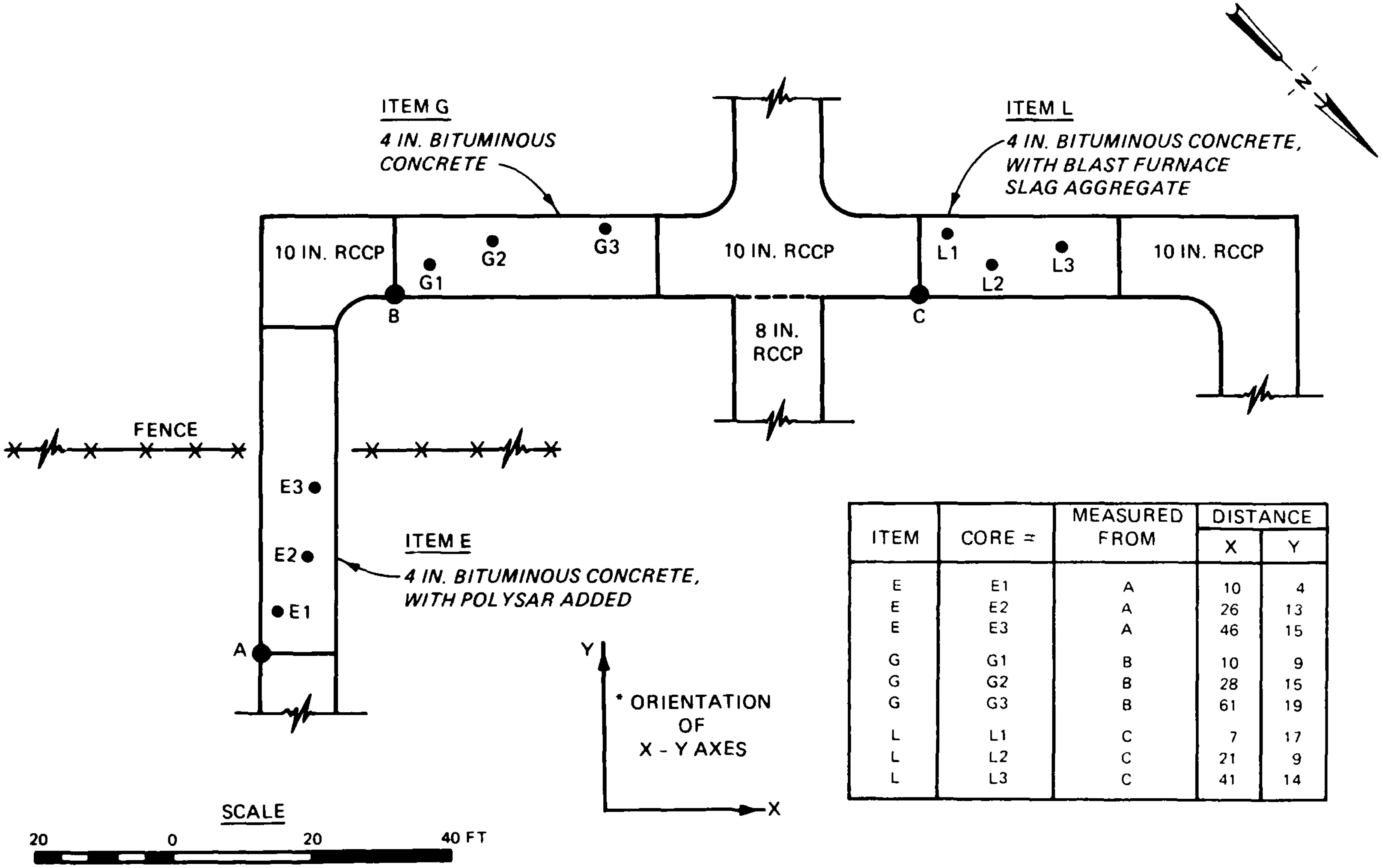


Figure 5. Location of concrete samples at Fort Stewart, Georgia



ITEM	CORE =	MEASURED FROM	DISTANCE X	DISTANCE Y
E	E1	A	10	4
E	E2	A	26	13
E	E3	A	46	15
G	G1	B	10	9
G	G2	B	28	15
G	G3	B	61	19
L	L1	C	7	17
L	L2	C	21	9
L	L3	C	41	14

Figure 6. Location of cores taken from bituminous concrete items

Photo 1. Damaged curb caused by tracked-vehicle traffic

Photo 2. Rounded pavement edge caused by tracked-vehicle traffic, Fort Hood

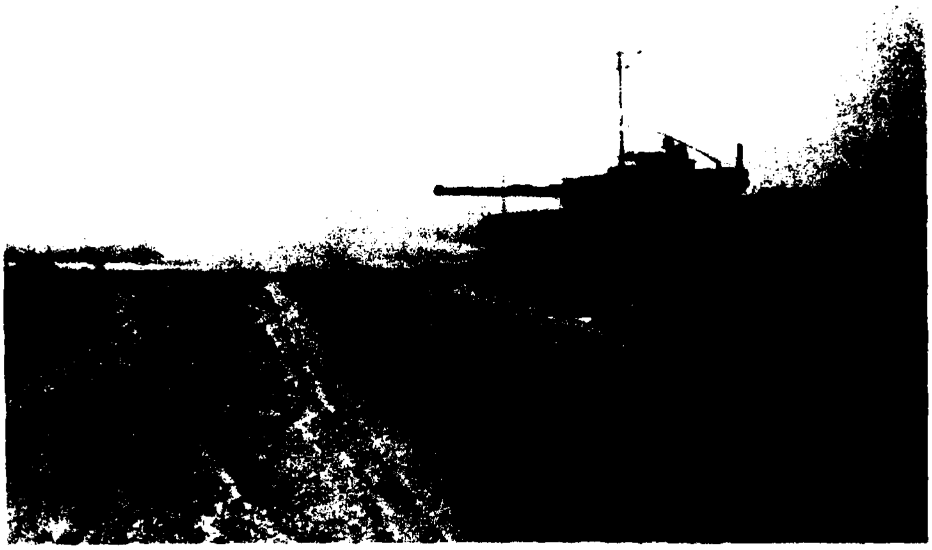


Photo 3. M-1 tank crossing paved road. (Note heavy dust resulting in obscured vision)

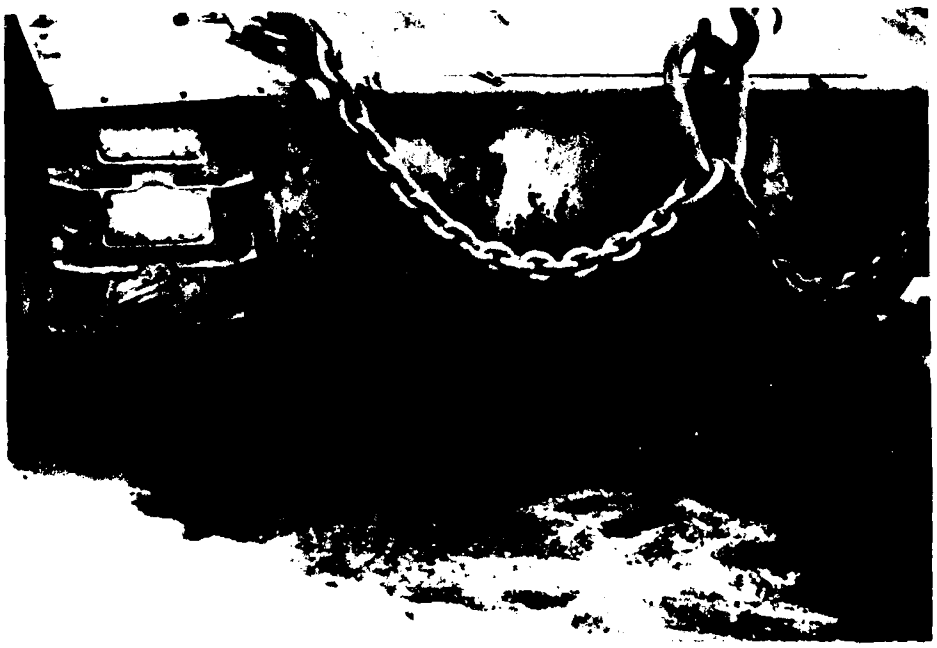


Photo 4. Fuel spills on pavement under tank

Photo 5. Pavement damaged by turning tracked vehicles

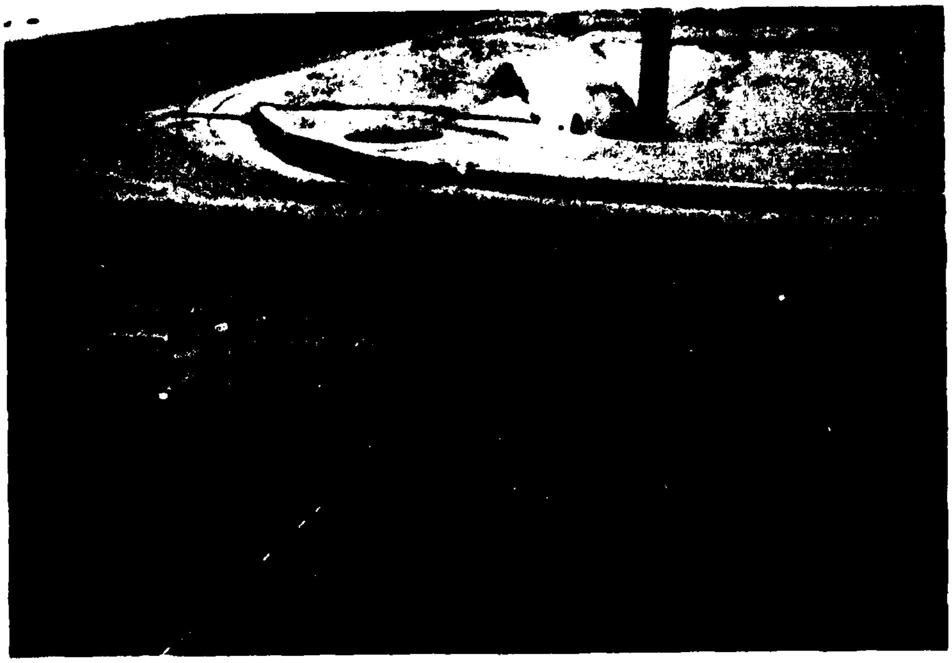


Photo 6. PCC intersection

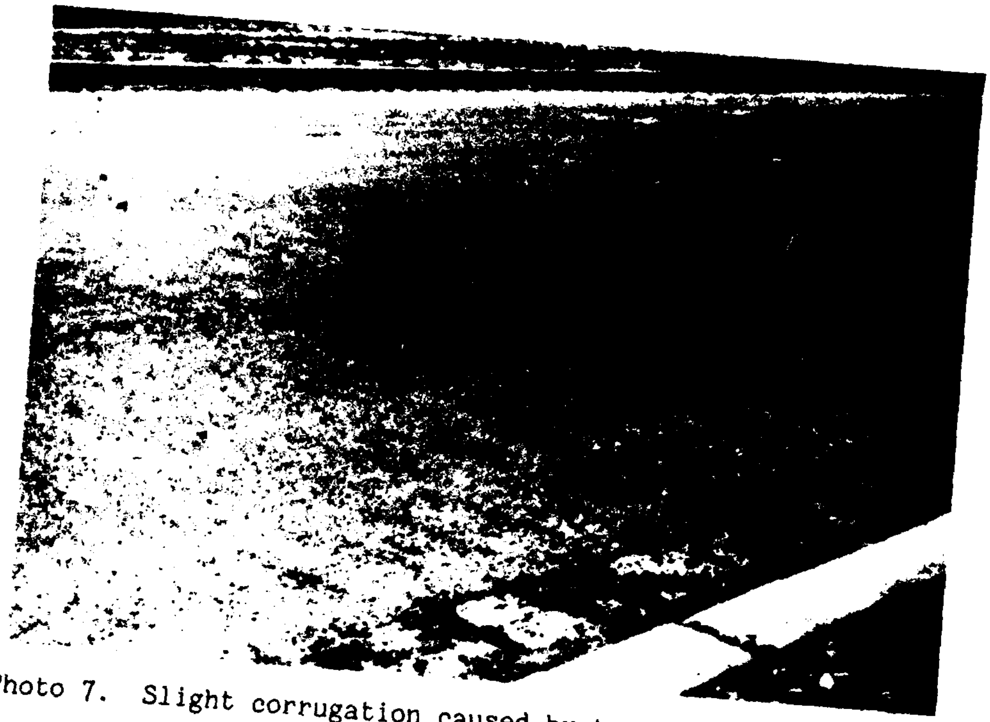


Photo 7. Slight corrugation caused by tracked-vehicle traffic

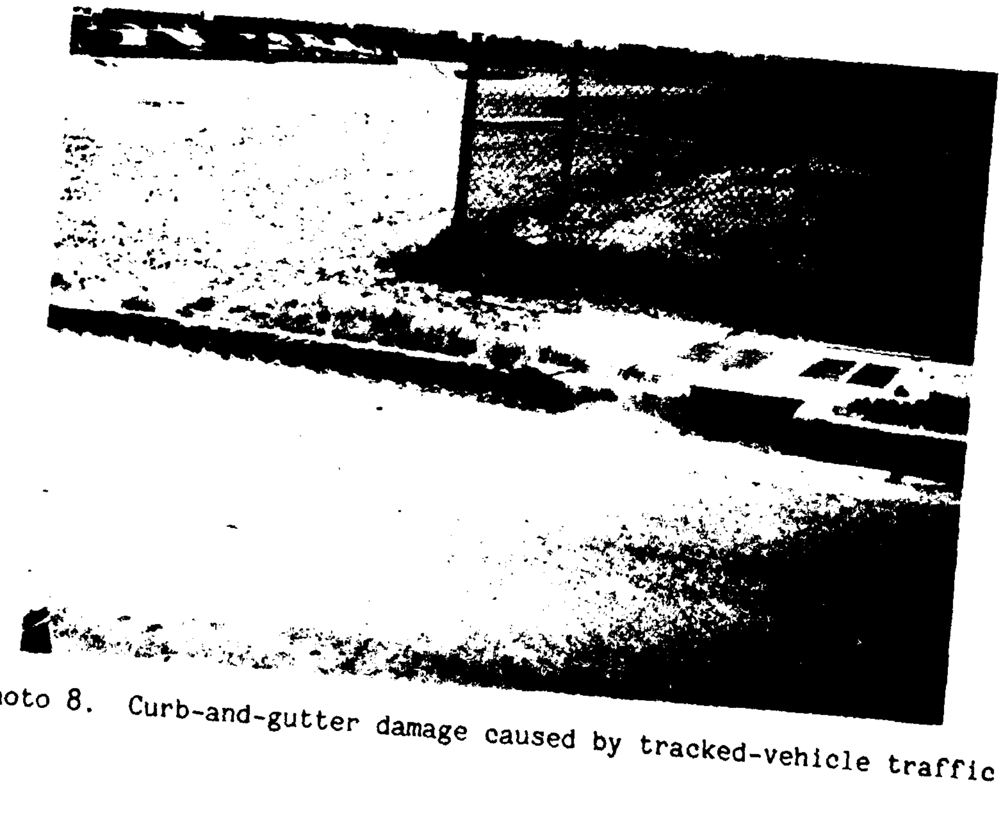


Photo 8. Curb-and-gutter damage caused by tracked-vehicle traffic

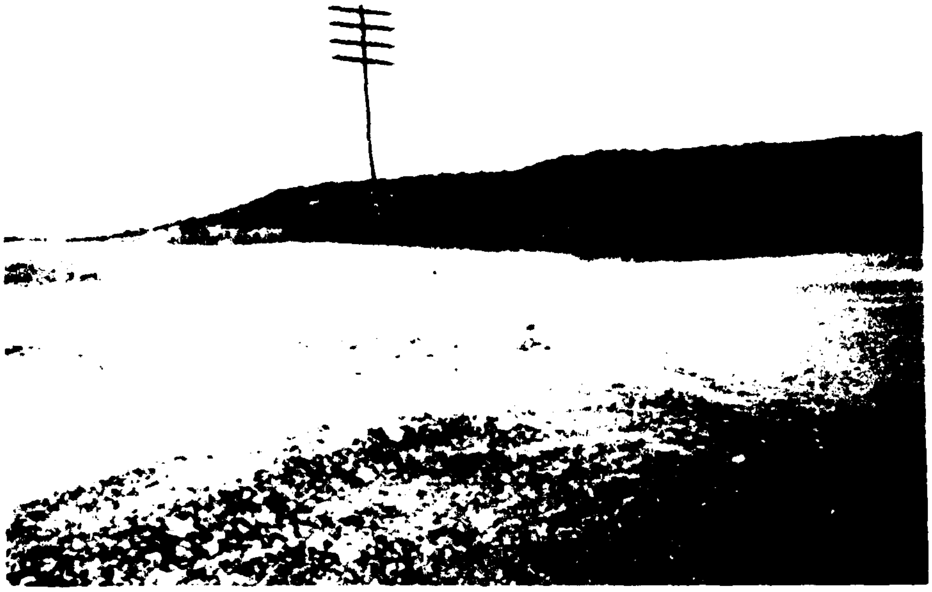


Photo 9. Dip on road at Fort Hood where PCC section intercepts asphalt cement road

Photo 10. Parking area damaged by fuel spills

Photo 11. Damage to road and shoulders caused by tracked-vehicle traffic

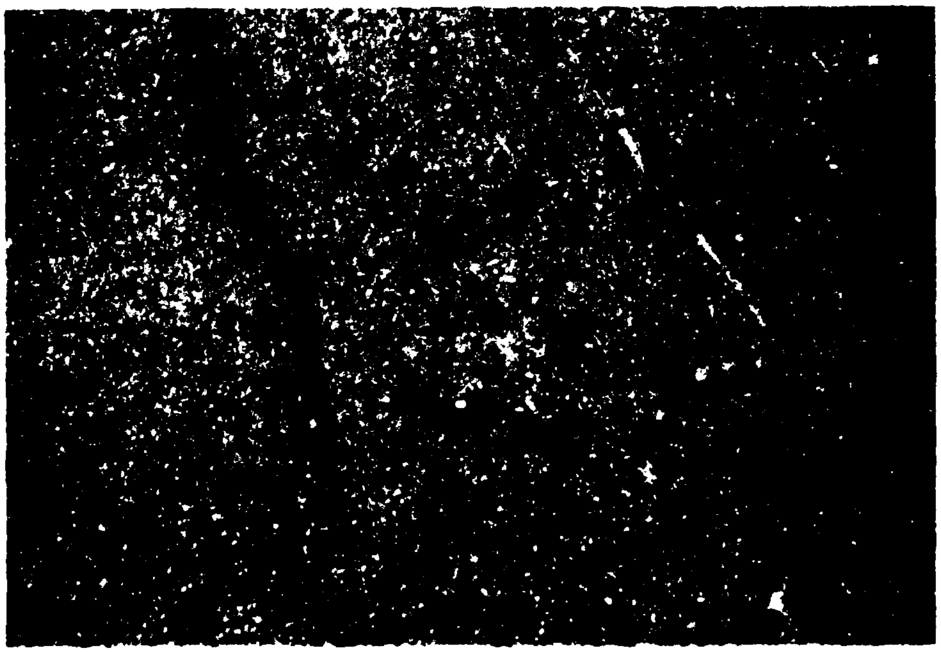


Photo 12. Surface texture of slag aggregate asphalt pavement, Detroit Arsenal

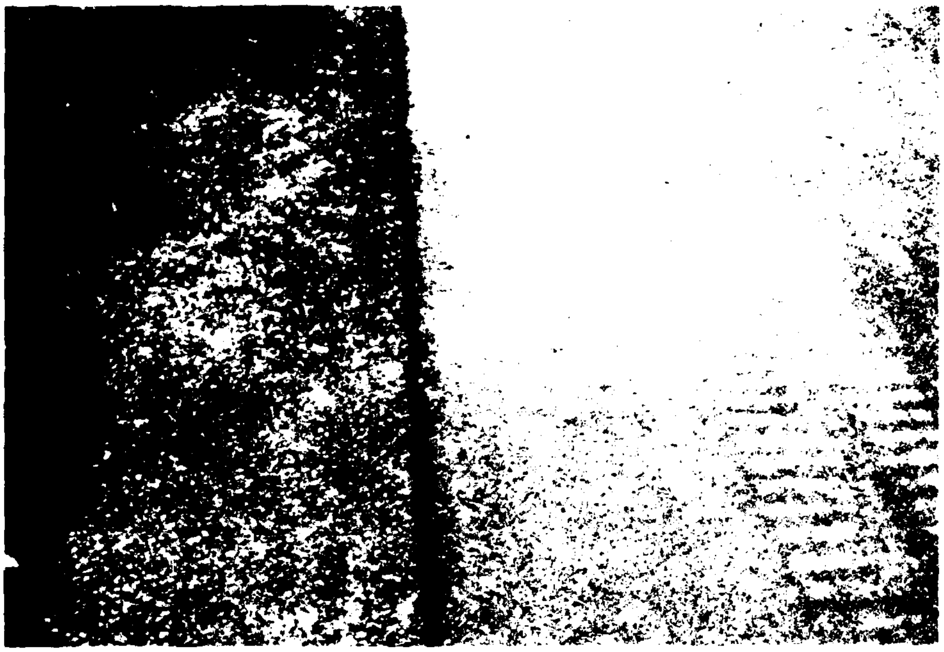


Photo 13. Pavement surface, Detroit Arsenal. (Note slight edge damage from tracked-vehicle traffic)

Photo 14. Surface scuffing from turning tracked vehicles

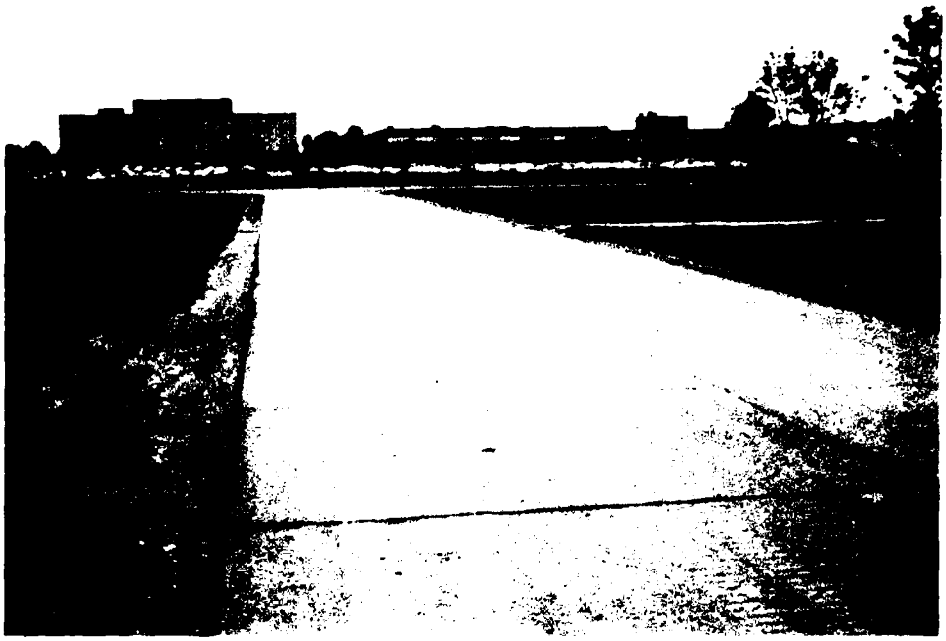


Photo 15. Asphalt surface with PCC contraction joints reflecting through

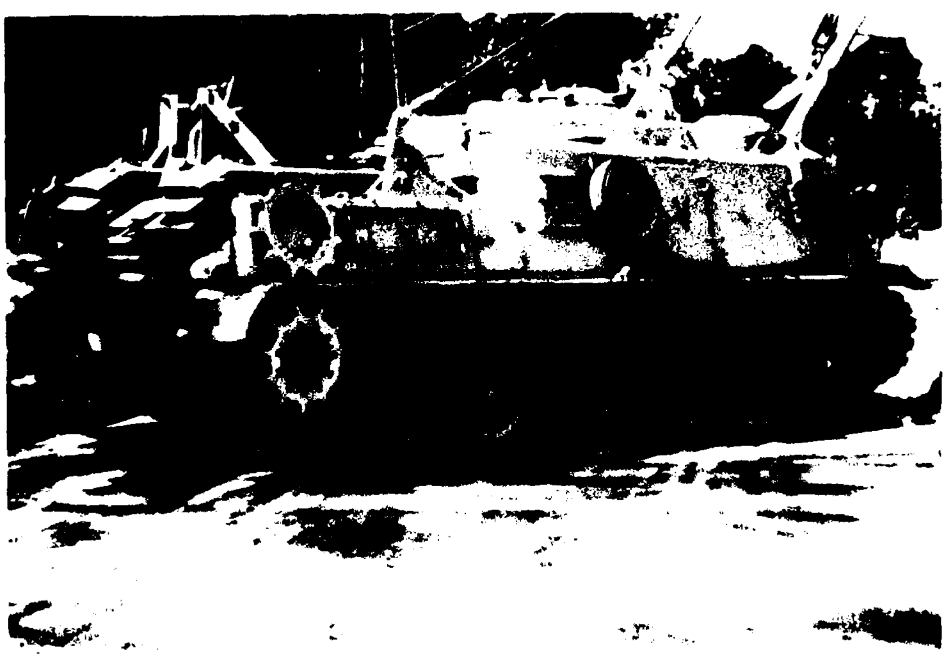


Photo 16. M-88 tank retriever used for locked-track-turning test

Photo 17. Steel fiber clumps (about 2 in. in diameter) that formed in the concrete

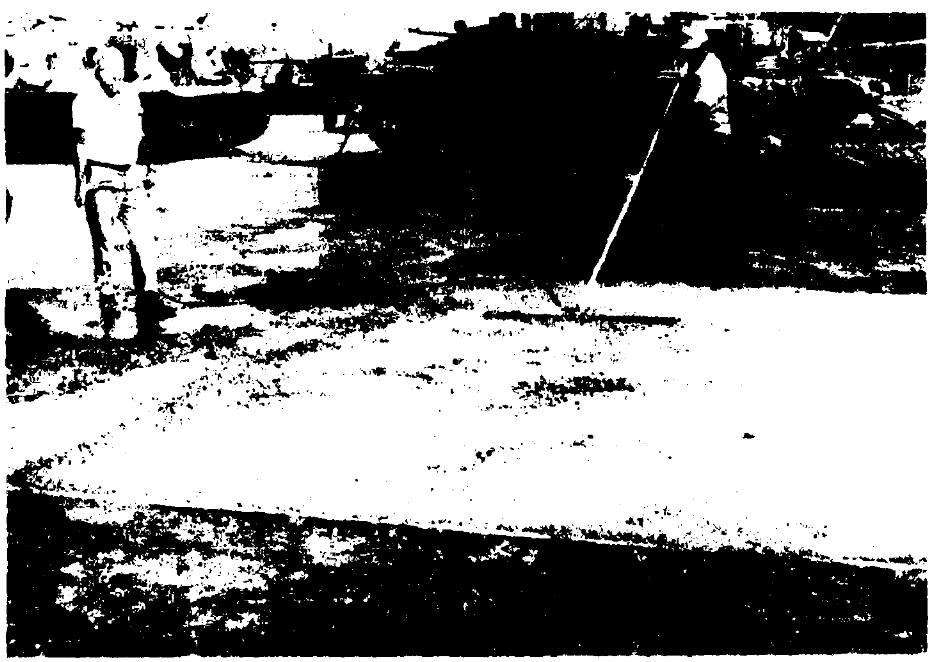


Photo 18. Floating the surface of Item A, FRC

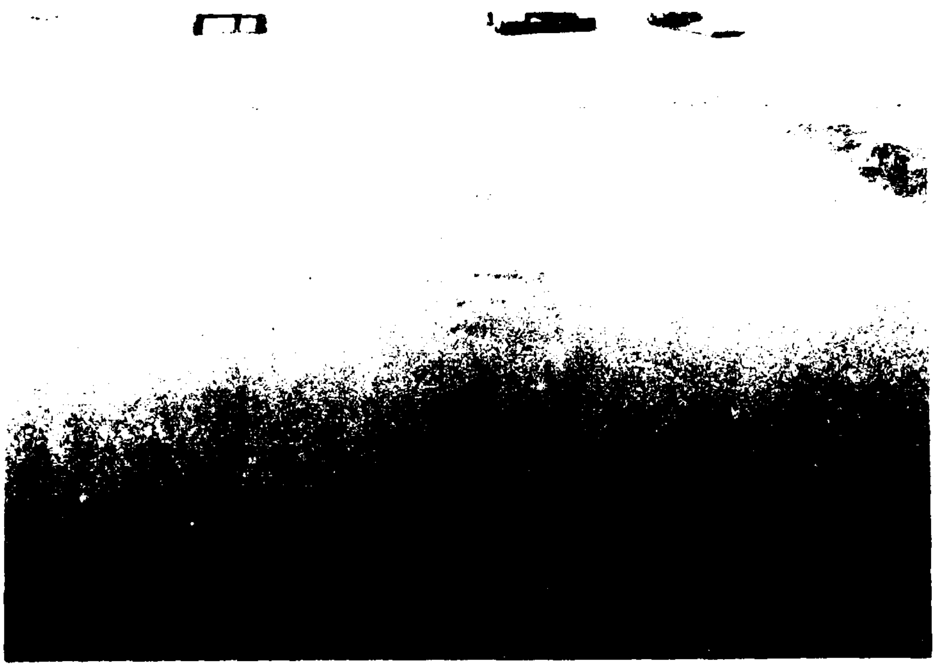


Photo 19. Final surface texture of Items A and B (foreground)

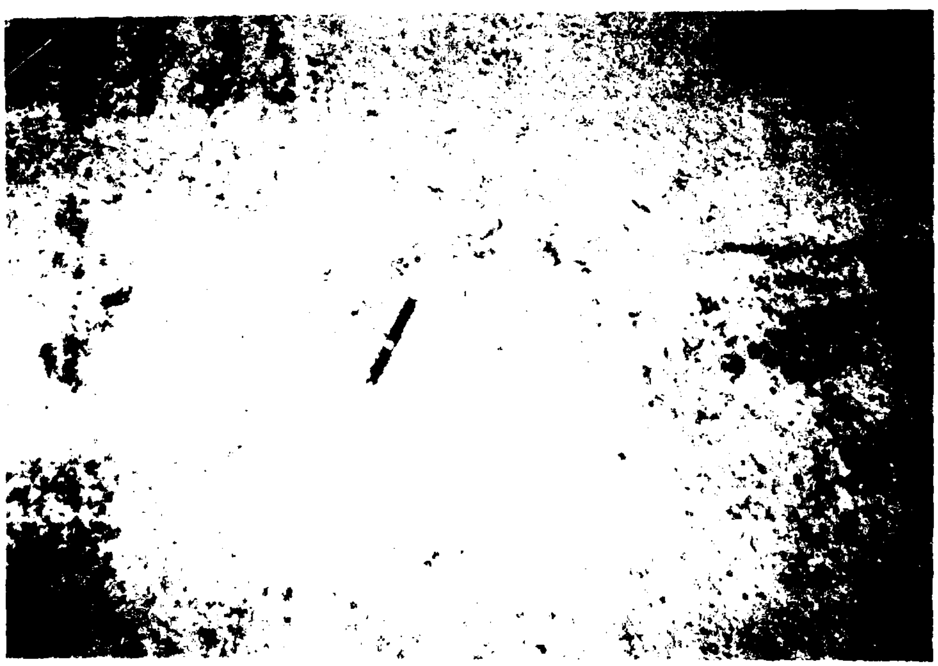


Photo 20. Surface texture of Item A, FRC

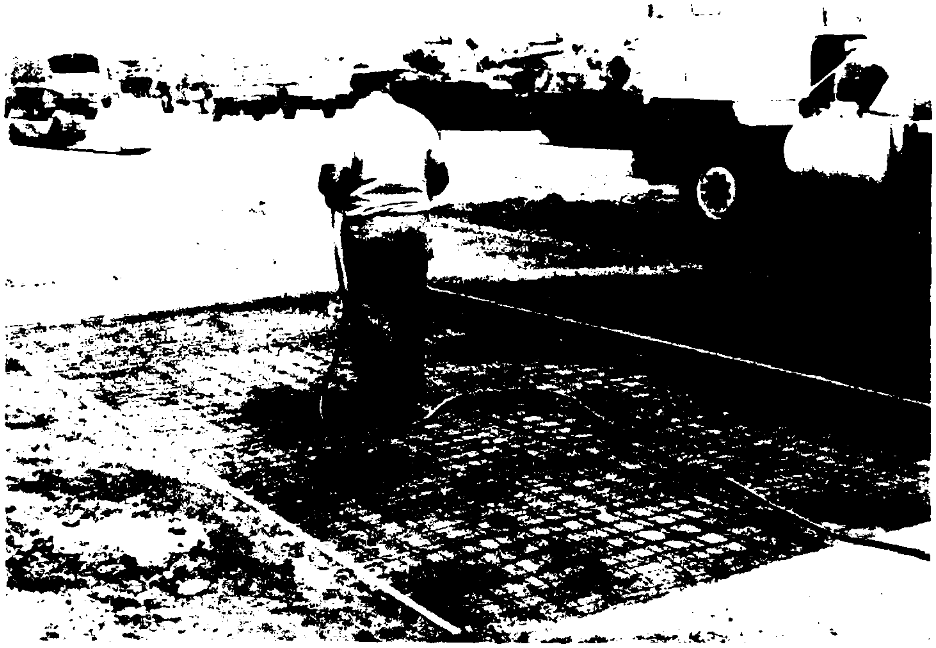


Photo 21. Wetting of base material. (Note the formwork and crown control)

Photo 22. Surface texture of Item B, reinforced wire-mesh concrete

Photo 23. Dumping RCC onto the base, Item C

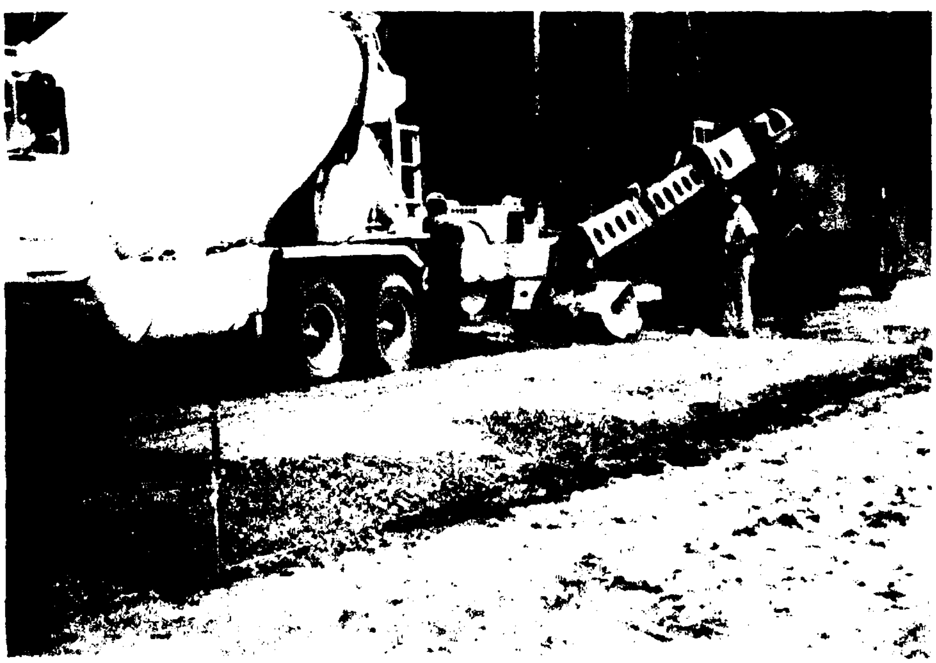


Photo 24. Spreading zero-slump concrete with a Gradall

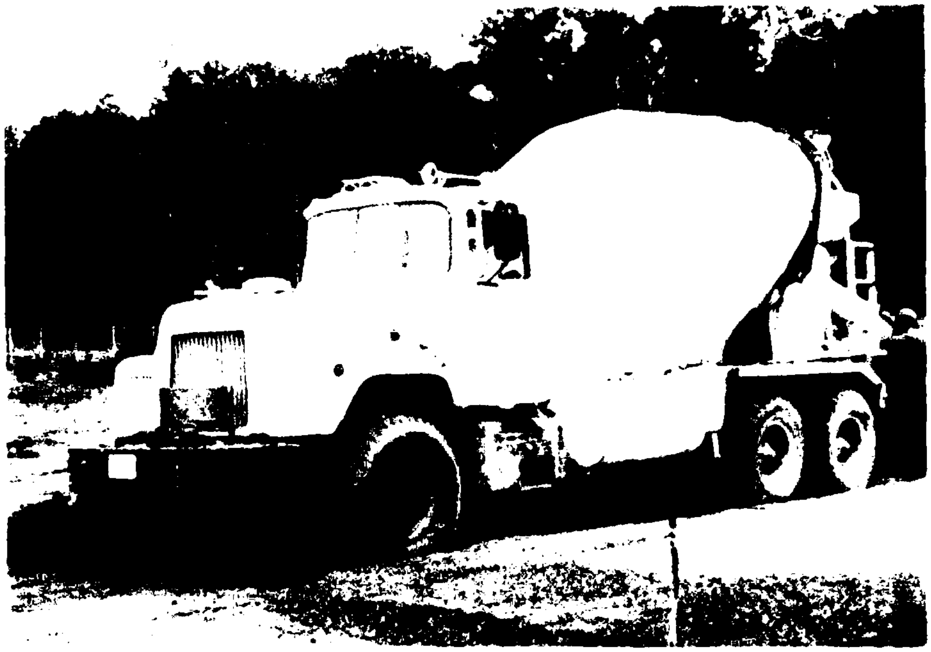


Photo 25. Transit mixer used to transport concrete

Photo 26. Consistency of this concrete proved ideal for compaction

Photo 27. M-88 tank retriever turning on Item C

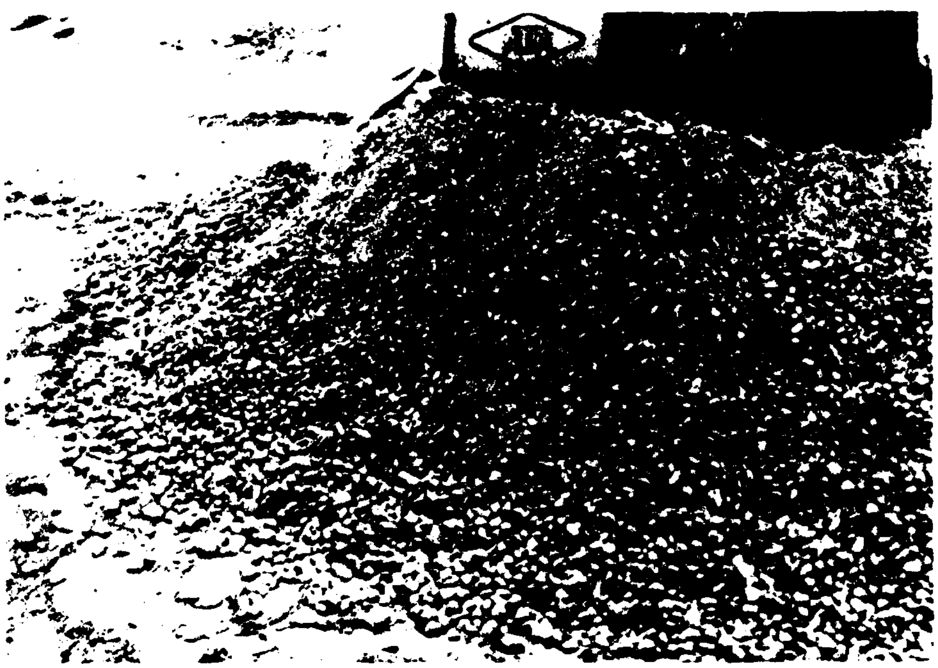


Photo 28. Dumping concrete directly onto prepared base. (Notice some segregation)

Photo 29. Condition of base after heavy rain, Item F

Photo 30. Surface of base material prior to placing RCCP

Photo 31. Placing RCCP along the vertical edge, Item E

Photo 32. Using a stringline to control grade and slope

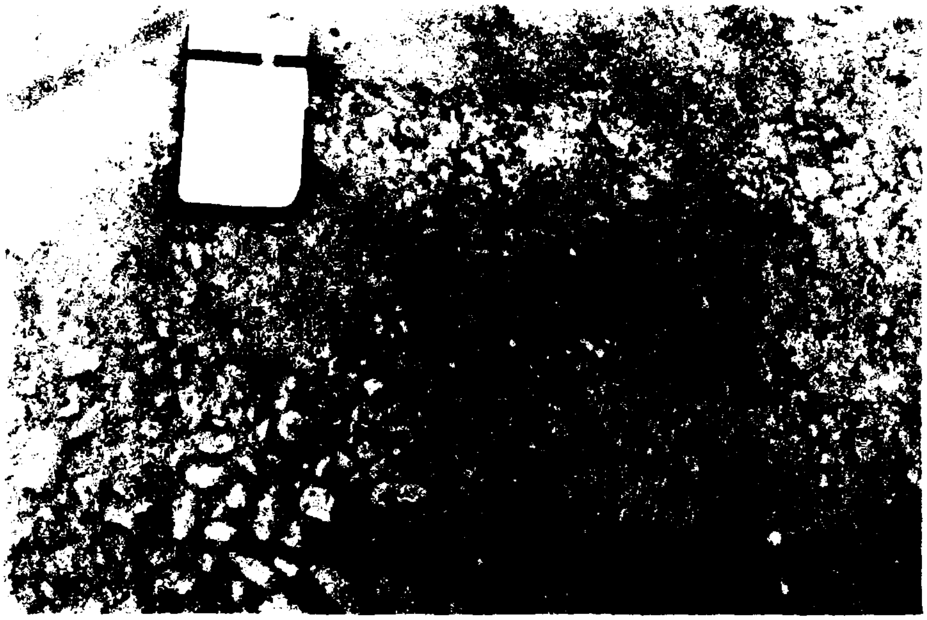


Photo 33. Completed surface texture, Item F

Photo 34. Compacted sandy-clay base course, Item H. (Note vertical face on Item L)

Photo 35. Working RCCP into the joint between Item G on the left and Item H (RCCP) on the right

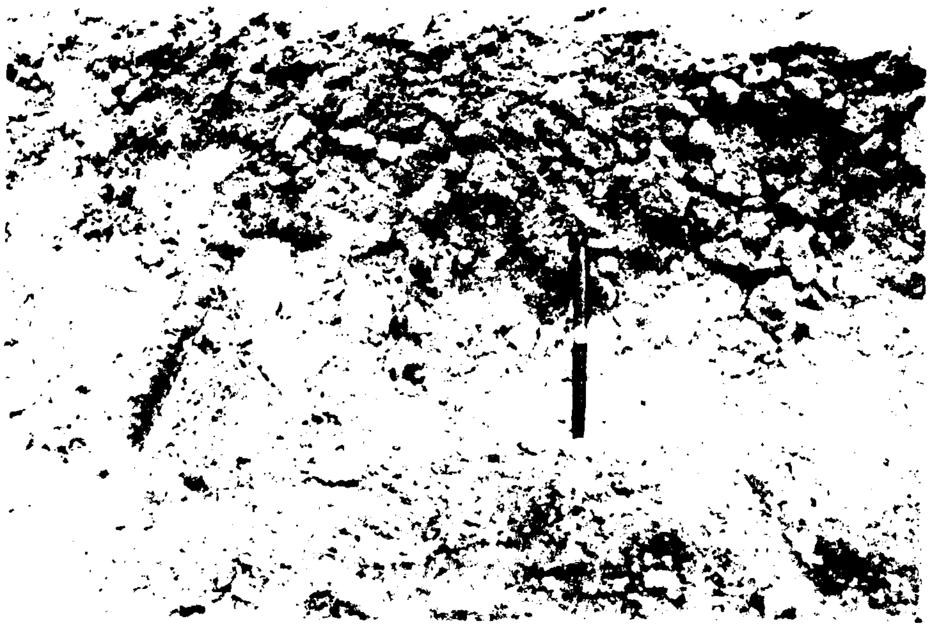


Photo 36. Joint edge between Items H and I. (Note dowel bar and uneven vertical face)

Photo 37. Spreading wet sand over the completed Item H. (Note *dowel bars across joint with Item I*)

Photo 38. RCCP has been placed in the far lane. (Notice dowel bars where items intersect)

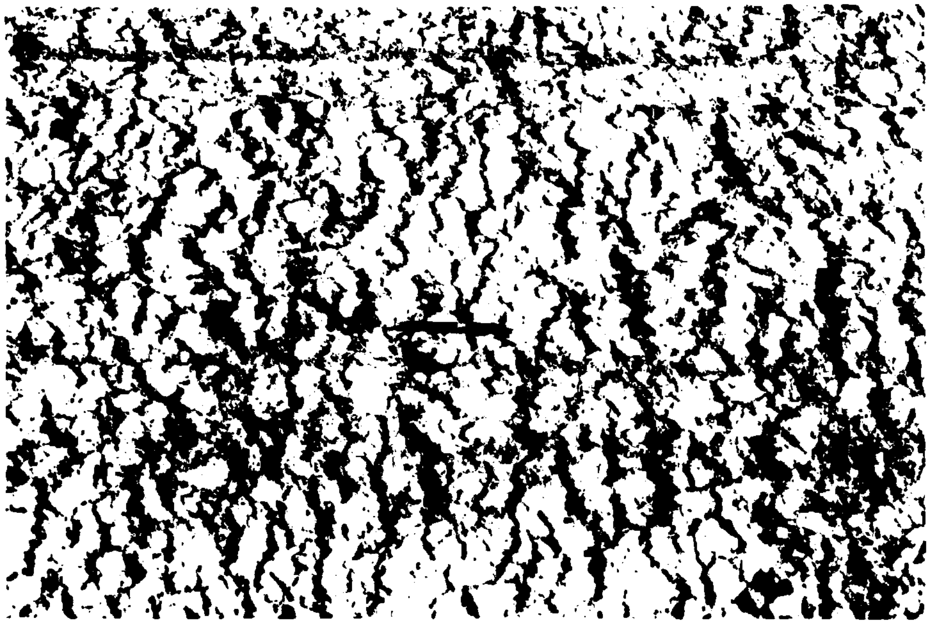


Photo 39. Surface texture of RCCP after two passes with the vibratory steel-wheeled roller in the static mode

Photo 40. Same surface after three passes each of the roller in alternating vibratory and static modes

Photo 41. Shrinkage crack, Item I

Photo 42. Shrinkage crack, Item J

Photo 43. Thickened edge along Item K (right) RCCP tapered out for about 5 ft over the conventional concrete (board was removed before RCCP was placed)

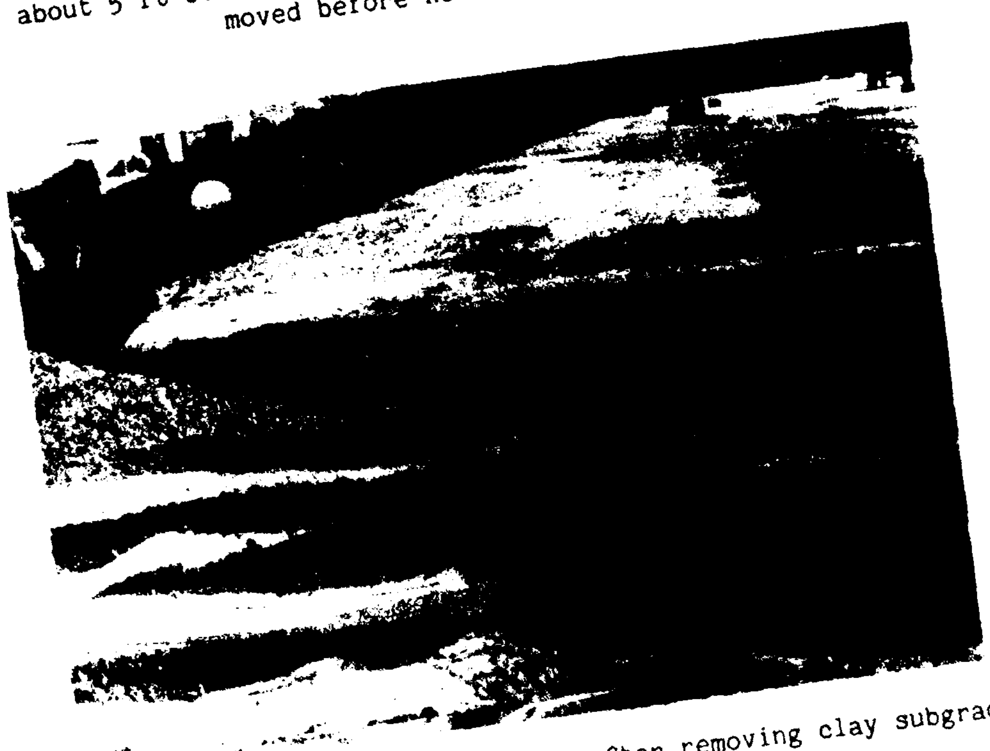


Photo 44. Placing sand in Item D after removing clay subgrade

Photo 45. Vibratory compactor, compacting silty sand base

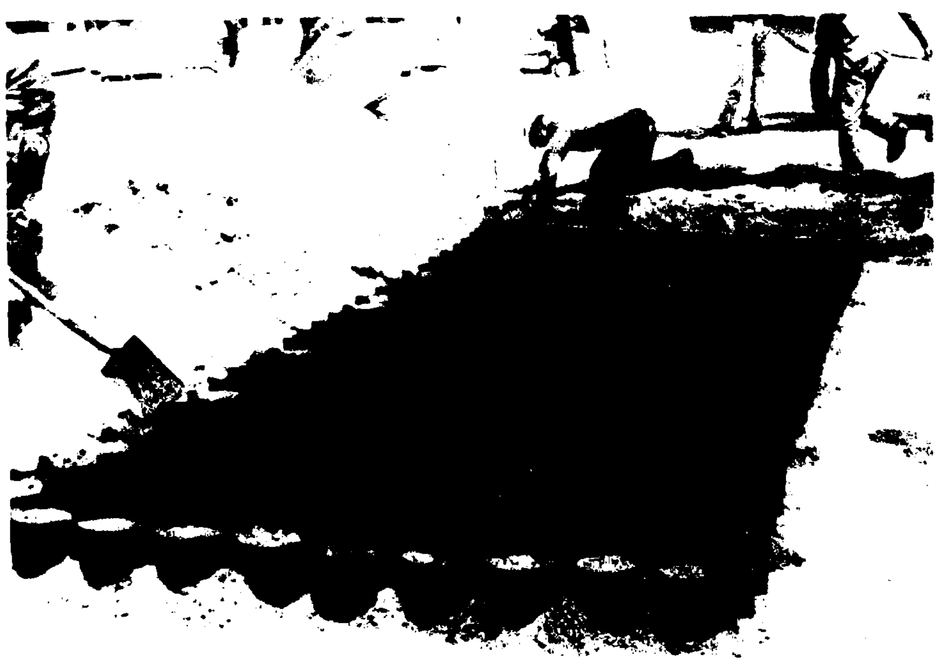


Photo 46. Placing the first section of sand grids

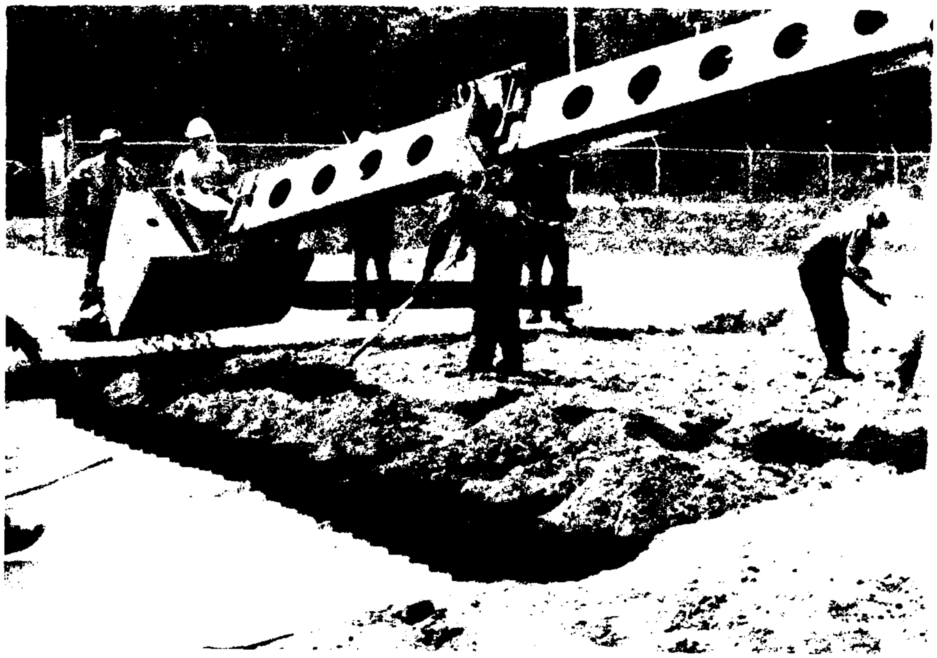


Photo 47. Filling sand grids with Gradall and hand shovels

Photo 48. Checking grade on loose surface sand prior to placing paving blocks

Photo 49. Restraining timbers placed along both edges, Item D

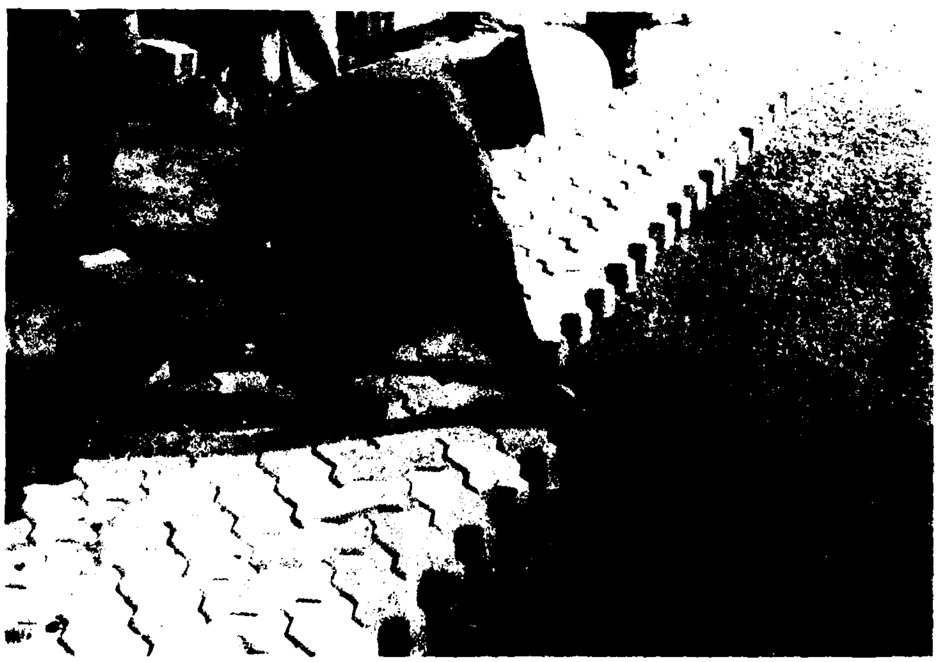


Photo 50. Placing paving blocks in a herringbone pattern

Photo 51. Cutting paving blocks with a hydraulic rock splitter

Photo 52. Filling cracks along edges of paving blocks and retaining timbers with a sand-cement mixture

Photo 53. Vibrating sand with a vibratory plate compactor into the cracks between the paving blocks

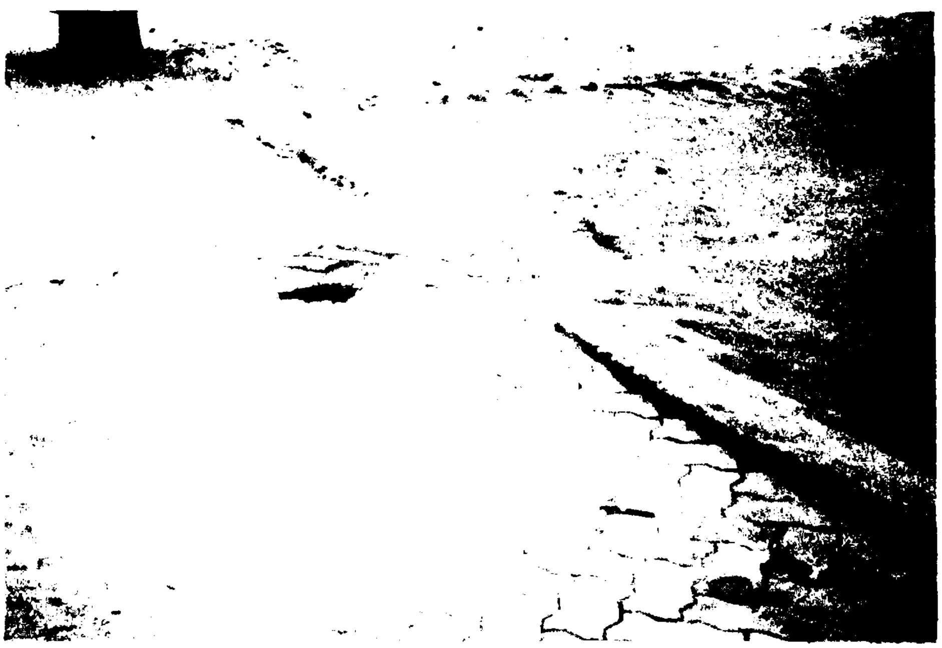


Photo 54. After turns of the retriever, Item D (foreground) and Item E (background)

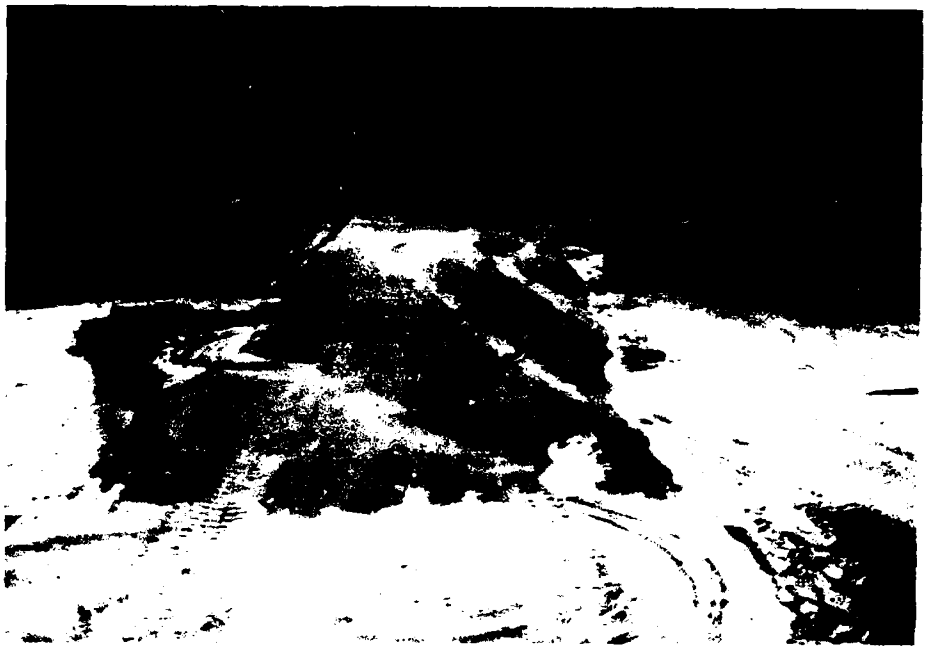


Photo 55. Settlement and rutting across paving blocks, Item D

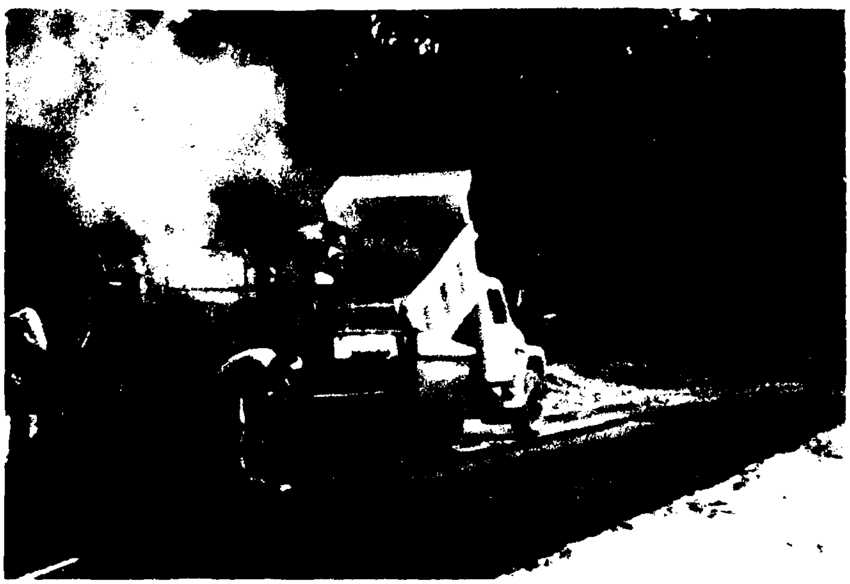


Photo 56. Placing latex asphalt concrete, Item E

Photo 57. Dual-diaphragm pump used to add latex to asphalt concrete

Photo 58. Twenty-ton rubber-tired roller

Photo 59. Sand stockpile containing some roots and fines

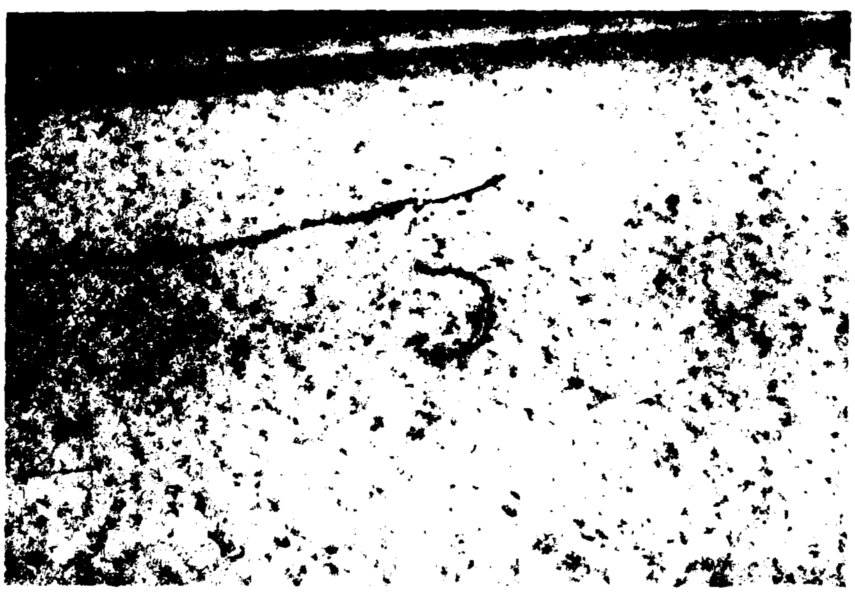


Photo 60. Root pulled from latex asphalt concrete surface

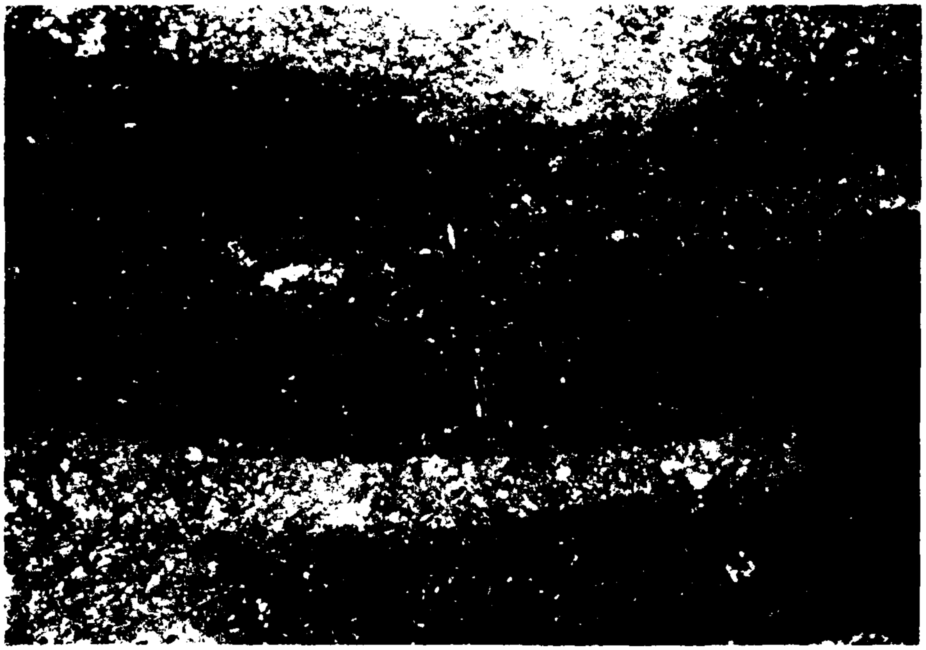


Photo 61. Scuff marks and small tear in the surface after locked-track turn by M-88 tank retriever, Item E

Photo 62. First-day construction, Item G (paver breakdown caused uneven lift thicknesses)

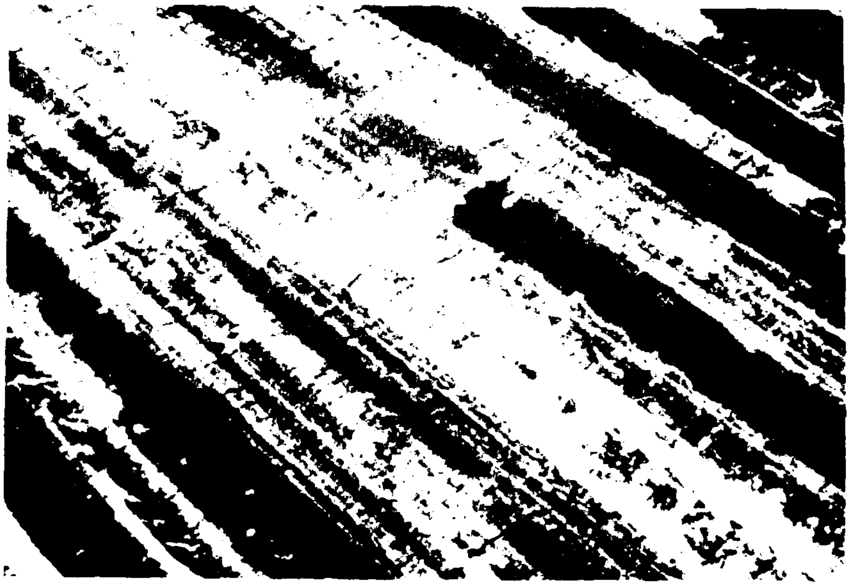


Photo 63. Cracks that formed after rolling, attributed to base failure

Photo 64. Torn surface from locked-track turn, Item G

Photo 65. Cracking in the corner, Item L

Photo 66. After 1 month of tracked-vehicle traffic, Item L

Photo 67. Dirt covering, from foreground to background (2 to 3 in.), Items L, H, G, and F

END

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